ICES WGACEGG REPORT 2018

ECOSYSTEM OBSERVATION STEERING GROUP

ICES CM 2018/EOSG:03

REF ACOM AND SCICOM

# Report of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas 7, 8 and 9 (WGACEGG)

19-23 November

Nantes, France

ICES CIEM International Council for the Exploration of the Sea Conseil International pour l'Exploration de la Mer

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## Contents

## Executive summary

The 2018 meeting of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas 7, 8 and 9 (WGACEGG) was held in Nantes, France on 19-23/11/2018. A joint meeting with the MEDIAS group coordinating acoustic surveys in the Mediterranean was held on 19-21/11/2018.

During this meeting, sardine and anchovy biomass indices derived from acoustic and Daily Egg Production Method (DEPM) surveys in ICES areas 8 and 9 have been evaluated and compared. Those indices have been provided to the ICES WGHANSA stock assessment group, to serve as fishery-independent input for analytical assessment purposes. DEPM and acoustic indices were derived based on data collected using independent methods. A session on survey design and precision has been held, opening up perspectives to further assess the bias and uncertainty impairing survey indices provided by the group. Acoustic and DEPM indices from quasi-synoptic surveys conducted in the Bay of Biscay in spring have been compared to assess the presence of potential bias in the biomass indices and to improve the precision of fish stock biomass estimates. No evidence of bias was found in those indices for the year 2018. IPMA and IEO have presented a new acoustic-trawl survey called IBERAS-JUVESAR, aiming at estimating sardine and anchovy recruitment in the 9a sub-area. The IBERAS-JUVESAR has been endorsed by the group.

The WACEGG group has updated its database of standard gridded maps covering the European Atlantic area and informing on the spatial dynamics of various parameters collected during the surveys coordinated under the auspices of the group (fish acoustic densities, anchovy and sardine egg abundance, surface temperature and salinity, seabird and cetaceans, etc.). The first results of an analysis of the time series of gridded maps (anchovy and sardine acoustic density and egg abundance, surface salinity and temperature) were presented. This study allowed quantitatively assessing the spatial and temporal distribution of anchovy and sardine over the last 15 years, and further define their habitats in European Atlantic waters in spring, based on survey data collected quasi-synoptically.

The timing and spatial coverage of DEPM and acoustic surveys that will be conducted by group members in 2018 have been reviewed and discussed during the meeting to optimise the monitoring of anchovy and sardine populations in their pelagic environment in the European Atlantic area.

A manual describing the protocols used during the DEPM surveys coordinated by the WGACEGG group has been reviewed during the meeting. It will be submitted to ICES as a contribution to the Series of ICES Survey Protocols (SISP) in early 2019. Methodologies used within the WGACEGG group for collecting and analysing acoustic data have been reviewed and summarised, with the objective of publishing a SISP manual of WGACEGG acoustic surveys after the 2019 meeting.

Methodological developments on the incorporation of identification catch data collected on research and commercial vessels in biomass assessment, repeated surveys in a restricted area, characterisation of anchovy individual backscatter, and on the assessment of fish biomass distributed near the sea surface (0-10m depth) have been discussed during the fisheries acoustics session. The ICES acoustic and trawl data portal has been presented, as well as methodologies to format and retrieve fisheries acoustic data stored in this facility.

Methodological developments for estimating spawning frequency for fish with determine or indetermine fecundity to improve accuracy and reduce cost and effort in applications of Egg Production Methods were presented during the DEPM session. Moreover, EcoTaxa, a recently developed web-based application to improve automatic identification of plankton images by the development of machine learning methods was presented. Besides, the use of CUFES in acoustic surveys to estimate the egg abundance of mackerel and horse mackerel and the advances in the used of CUFES have been discussed during the DEPM session.

# 1 Administrative details

**Working Group name**

Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas 7, 8 and 9

**Year of Appointment within the current cycle**: 2018

**Reporting year within the current cycle (1, 2 or 3):** 2

**Chair(s):** Maria Santos, Spain & Mathieu Doray, France

**Meeting venue:** Nantes, France

**Meeting dates:** 19–23 November 2018

## 2 Terms of Reference

| ToR | Description | Background | Science Plan Codes | Duration | Expected Deliverables |
|---|---|---|---|---|---|
| **a** | **Provide echo-integration and Daily Egg Production Method (DEPM) estimates for sardine and anchovy in ICES sub-Areas 7, 8 and 9** | **a) Advisory Requirements**<br>**b) Requirements from other EGs** | **3.1** | **3 years** | **Abundance and biomass estimates by age group. Fish spatial distribution will be provided to WGHANSA by the end of the WGACEGG meeting.**<br>**Datasets will be published in the ICES facility when available.** |
| b | Analyse sardine and anchovy (adults and eggs), spatial and temporal distribution and their habitats in European waters | a) Science Requirements<br>b) Requirements from other EGs | 1.5 | Year 3 | Manuscript and/or technical report in 2019 |
| c | Provide ecosystem data such as temperature, salinity, plankton diversity, top predators abundances, egg densities and backscattering for sardine, anchovy and other small pelagic fish for pelagic ecosystem monitoring (e.g. MSFD) | a) Science Requirements<br>b) Requirements from other EGs | 1.4, 1.5 | 3 years | Gridded maps updated every year.<br>Datasets will be published in the ICES facility when available. |
| d | Assess developments in the technologies and data analyses for the application of | a) Science Requirements<br>b) Advisory Requirements | 3.3 | 3 years | New methodologies reported in annual WG report, available to the public |

| | | | | | |
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| | both acoustics and the DEPM (on Egg Production or adult parameters). | c) Requirements from other EGs | | | one month after the meeting. |
| e | Improve and assess the suitability of CUFES data for anchovy and sardine egg production estimates in areas 8 and 9. | a) Science Requirements<br>b) Advisory Requirements<br>c) Requirements from other EGs | 3.3 | 3 years | Advances reported in annual WG report, available to the public one month after the meeting. |
| f | Coordination and standardization of the surveys | a) Science Requirements<br>b) Advisory Requirements | 3.1, 3.2 | 3 years | Annual plan for coordinated surveys.<br>Updated survey protocols |
| g | Development and standardization of data processing methods for DEPM and acoustics<br>for surveys in Atlantic and Mediterranean waters | a) Science Requirements<br>b) Advisory Requirements<br>c) Requirements from other EGs | 3.1, 3.2 | 3 years | Updated data processing protocols shared with the MEDIAS group (Mediterranean acoustic survey group) |
| h | Provide echo-integration estimates for other species (mainly blue whiting, mackerel, horse mackerel, chub mackerel and boarfish) ICES sub-Areas 8 and 9 | a) Advisory Requirements<br>b) Requirements from other EGs | 3.5 | 3 years | Biomass per age group when available otherwise per length classes and spatial density distribution, provided to WGWIDE before the WG annual meeting.<br>Datasets will be published in the ICES facility when available. |

| | | | | | |
|---|---|---|---|---|---|
| i | Ensure QAQC procedures are in place | ICES aims to have a quality assurance process for data collections used in the provision of advice. One element of this is that all procedures describing the data collection are adequately described. | 3.1 | 3 years | Develop an independent SISP for the data collection and product specification conducted under the auspices of WGACEGG |
| j | Compare acoustic and DEPM biomass estimates of anchovy and sardine to improve the precision of stock estimates | a) Science Requirements<br>b) Advisory Requirements<br>c) Requirements from other EGs | - | 3 years | Advances reported in annual WG report, available to the public one month after the meeting |
| k | Develop the use of imagery techniques to characterise the distribution of mesozooplankton (including fish eggs) and possibly microplastics in areas 8 and 9, based on CUFES and/or PairoVET samples. | a) Science Requirements<br>b) Requirements from other EGs | 1.2 | 3 years | Advances reported in annual WG report, available to the public one month after the meeting |

# 3 Summary of work plan

| | |
|---|---|
| **Year 1** | **Annual meeting:**<br>• Session on acoustic data collection and analysis<br>• Session on DEPM data collection and analysis<br>• Session on acoustic and DEPM indices comparison<br>• Update of gridded maps of ecosystem data derived from surveys<br>• Session on methods for the analysis of series of gridded maps of ecosystem data<br>• Session to analyse progress on sardine and anchovy egg production estimates from CUFES |
| **Year 2** | **Annual meeting, including a joint session with MEDIAS (Mediterranean acoustic survey group):**<br>• Session on acoustic data collection and analysis<br>• Session on DEPM data collection and analysis<br>• Session on anchovy and sardine eggs staging intercalibration exercises<br>• Session on acoustic and DEPM indices comparison<br>• Session on survey design<br>• Update of gridded maps of ecosystem data derived from surveys<br>• Session on methods for the analysis of series of gridded maps of ecosystem data<br>• Session to analyse progress on sardine and anchovy egg production estimates from CUFES |
| **Year 3** | **Annual meeting:**<br>• Session on acoustic data analysis and developments<br>• Session on DEPM data analysis and developments<br>• Session on anchovy and sardine eggs identification and staging using automated methodologies<br>• Session on acoustic and DEPM indices comparison<br>• Writing of a report or manuscript on the analysis of series of WGACEGG gridded maps of ecosystem data<br>• Session to analyse progress on sardine and anchovy egg production estimates from CUFES<br>• Submission of the WGACEGG DEPM and acoustic Survey Protocols (SISP) |

# 4 List of outcomes and achievements of the WG in this delivery period

The following outcomes and achievements were obtained during 2018 by WGACEGG:

**Sardine and anchovy biomass indices derived from acoustic and DEPM surveys used as input fishery-independent data for analytical assessment purposes in ICES WGHANSA:**

- Anchovy total biomass estimated by BIOMAN2018 DEPM survey in 8abcd.
- Anchovy proportion of biomass at age 1 estimated by BIOMAN2018 DEPM survey in 8abcd
- Anchovy total biomass estimated by PELGAS2018 acoustic survey in 8abd.
- Anchovy proportion of biomass at age 1 estimated by PELGAS2018 acoustic survey in 8abd.
- Anchovy juvenile abundance index estimated by JUVENA2018 acoustic survey in 8abcd.
- Anchovy total biomass estimated by PELAGO18 acoustic survey in 9a
- Anchovy total biomass estimated by ECOCADIZ 2018-07 acoustic survey in 9a South
- Anchovy population in numbers-at-age in 9a South from ECOCADIZ 2018-07 acoustic survey
- Sardine total biomass in 9a from PELAGO17 acoustic survey
- Sardine population in numbers-at-age in 9a from PELAGO18 acoustic survey
- Sardine total biomass in 9a north and 8c from PELACUS0318 acoustic survey
- Sardine population in numbers-at-age in 8c and 9a north from PELACUS0317 acoustic survey
- Sardine total biomass estimated in 8abd from PELGAS2018 acoustic survey.
- Sardine population in numbers-at-age in 8abd from PELGAS2017 acoustic survey
- Sardine egg abundance in 8abd and 8abcd from BIOMAN2018 DEPM survey
- Sardine spawning stock biomass in 8c and 9a from SAREVA0317 and PT-DEPM17-PIL (preliminary updated results)

**Other indices used as biological information at the WGHANSA:**

- Anchovy Spawning Stock biomass estimated by BOCADEVA 2017-07 DEPM survey in 9a South (final results)
- Anchovy daily fecundity (and associated parameters W; F; S; R) in area 8abcd from BIOMAN2018 DEPM survey
- Anchovy total daily egg production in area 8abcd from BIOMAN2018 DEPM survey
- Sardine total daily egg production in 8c and 9a from SAREVA0317 and PT-DEPM17-PIL
- Sardine daily fecundity (DF)and spawning-stock biomass in 8c and 9a from SAREVA0317 and PT-DEPM17-PIL
- Sardine maturity ogives and mean weight at age from DEPM (SAREVA0317, PT-DEPM17-PIL) and acoustic surveys (PELAGO17 and PELACUS0317)
- Sardine and anchovy numbers-at-age estimated by PELACUS0318 acoustic surveys in 9aN and 8c
- Sardine and anchovy numbers-at-age in 8abd from PELGAS2018 acoustic survey
- Sardine total biomass in 9a South from ECOCADIZ 2018-07 acoustic survey

- Sardine population in numbers by size class in 9a South from ECOCADIZ 2018-07 acoustic survey
- Anchovy numbers-at-age in 8abcd from BIOMAN2018 DEPM survey
- Anchovy mean weight and length-at-age, and biomass at age in 8abcd from BIOMAN2018 DEPM survey
- Anchovy mean weight and length-at-age, and biomass at age in 8abd from PELGAS2018 acoustic survey.
- Anchovy mean weight and length-at-age, and biomass at age in 9a South from ECOCADIZ 2018-07 acoustic survey
- Sardine mean weight and length-at-age in 8abd from PELGAS2018 surveys
- Sardine mean weight and length-at-age in 8c and 9a north from PELACUS0318 survey
- Sardine mean weight and length-at-age in 9a from PELAGO18 survey
- Sardine mean weight and length, and biomass by size class in 9a South from ECOCADIZ 2018-07 acoustic survey

**Other acoustic indices used as biological information at the WGWIDE:**

- Horse mackerel, boar fish, mackerel and blue whiting distribution and numbers-at-age in 9a and 8c from PELACUS0318

**Other survey-derived products:**

- Sardine, anchovy and sprat distribution and numbers-at-age in area 7 from PELTIC18 survey
- Sardine egg abundances from CUFES sampling during surveys PELAGO18, PELACUS0318 and PELGAS2018
- Sardine egg abundances from CUFES sampling during ECOCADIZ2018-07
- Anchovy egg abundances from CUFES sampling during surveys PELAGO18, PELACUS0318 and PELGAS2018
- Anchovy egg abundances from CUFES sampling during acoustics survey ECOCADIZ2018-07
- Sardine egg abundances from CUFES sampling during DEPM survey BIOMAN2018
- Anchovy egg abundances from CUFES sampling during DEPM surveys BIOMAN2018
- Sardine total daily egg production Ptot from CUFES from PELGAS2018
- Anchovy total daily egg production Ptot from CUFES from PELGAS2018
- SST and SSS from acoustics surveys PELAGO18, PELACUS0318 and PELGAS2018
- SST and SSS from acoustics survey ECOCADIZ2018-07
- SST and SSS from DEPM survey BIOMAN2018
- SST and SSS from acoustics surveys PELTIC2018 and JUVENA2018
- Marine birds and mammals, human activities and debris distribution obtained during BIOMAN2018 DEPM survey
- Marine birds and mammals census during acoustics surveys PELGAS2018, PELACUS0318 and PELAGO18
- Marine birds and mammals census during acoustics survey ECOCADIZ2018-07
- Marine birds and mammals census during autumn surveys PELTIC2018 and JUVENA2018

### Grid data/maps Database

The WGACEGG group maintains a database of standard maps covering the European Atlantic area informing on the spatial dynamics of various parameters collected during the surveys coordinated under the auspices of the group (fish acoustic densities, egg/m$^2$, egg/m3, surface temperature and salinity, bird and mammals, etc). These standard maps can be used to compute global indices describing the state of the European Atlantic pelagic ecosystem in spring and autumn. The Group will continue to compile the data and will explore its utilization in collaborative studies.

### Publications

Boyra, G., Moreno, G., Sobradillo, B., Pe, I., Sancristobal, I., and Demer, D. A. Target strength of skipjack tuna (Katsuwanus pelamis) associated with fish aggregating devices (FADs). ICES Journal of Marine Science (2018), 75(5), 1790-1802. Doi: 10.1093/icesjms/fsy041.

Colas, F., Tardivel, M., Perchoc, J., Lunven, M., Forest, B., Guyader, G., Danielou, M.M., Le Mestre, S., Bourriau, P., Antajan, E., Sourisseau, M., Huret, M., Petitgas, P., Romagnan, J.B., 2018. The ZooCAM, a new in-flow imaging system for fast onboard counting, sizing and classification of fish eggs and metazooplankton. Progress in Oceanography, Multidisciplinary integrated surveys 166, 54–65. https://doi.org/10.1016/j.pocean.2017.10.014

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Doray, M., Petitgas, P., Huret, M., Duhamel, E., Romagnan, J. B., Authier, M., Dupuy, C., et al. 2018b. Monitoring small pelagic fish in the Bay of Biscay ecosystem, using indicators from an integrated survey. Progress in Oceanography, 166: 168–188.

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Huret, M., Bourriau, P., Doray, M., Gohin, F., and Petitgas, P. 2018. Survey timing vs. ecosystem scheduling: Degree-days to underpin observed interannual variability in marine ecosystems. Progress in Oceanography, 166: 30–40.

Louzao, M., Isabel García-Barón, Anna Rubio, Udane Martínez, José Antonio Vázquez, José Luis Murcia, Enrique Nogueira and Guillermo Boyra. Understanding the 3D environment of pelagic seabirds from multidisciplinary oceanographic surveys to advance ecosystem-based monitoring. Accepted in Marine Ecology Progress Series, December 2018.

Massé, J., Uriarte, A., Angélico, M. M., and Carrera, P. 2018. Pelagic survey series for sardine and anchovy in ICES subareas 8 and 9 (WGACEGG) – Towards an ecosystem approach. ICES Coop. Res. Rep., 332.

Petitgas, P., Huret, M., Dupuy, C., Spitz, J., Authier, M., Romagnan, J. B., and Doray, M. 2018. Ecosystem spatial structure revealed by integrated survey data. Progress in Oceanography, 166: 189–198.

Saavedra, C., Gerrodette, T., Louzao, M., Valeiras, J., García, S., Cerviño, S., Pierce, G.J., Santos, M.B. 2018. Assessing the Environmental Status of the common dolphin (*Delphinus delphis*) in North-western Spanish waters using abundance trends and safe removal limits. Progress in Oceanography 166:66-75.

Szalaj, D., L. Wise, L., Rodríguez-Climent, S., Angélico, M.M., Marques, V., Chaves, C., Silva, A. and H. Cabral, H. 2018. A GIS-based framework for addressing conflicting objectives in the context of an ecosystem approach to fisheries management—a case study of the Portuguese sardine fishery. ICES Journal of Marine Science, 75 (6): 2070–2087.

Veiga-Malta, T., Szalaj, D., Angélico, M.M., Azevedo, M., Farias, I., Garrido, S., Lourenço, S., Marçalo, A., Marques, V., Moreno A., Oliveira, P.B., Paiva, V.H., Prista, N., Silva, C., Sobrinho-Gonçalves, L., Vingada, J., and Silva, A. 2018. First representation of the trophic structure and functioning of the Portuguese continental shelf ecosystem: insights on the role of sardine, Marine Ecology Progress Series, DOI: 10.3354/meps12724

Virgili, A., Authier, M., Boisseau, O., Cañadas, A., Claridge, D., Cole, T., Corkeron, P., Dorémus, G., David, L., Di-Méglio, M., Dunn, C., Dunn, T.E., García Barón, I., Laran, S., Lewis, M., Louzao, M., Luiz Sancho, L., Mannocci, L., Martínez-Cedeira, J., Palka, D., Panigada, S., Pettex, E., Roberts, J., Santos, M.B., Van Canneyt, O., Vázquez, J.A., Monestiez, P., Ridoux, V. In press. Combining datasets into a basin wide approach to model habitats of deep-divers. Global Ecology and Biogeography.

Waggitt JJ, Cazenave PW, Howarth LM, Evans PGH, van der Kooij J, Hiddink JG. 2018 Combined measurements of prey availability explain habitat selection in foraging seabirds. Biol. Lett. 14: 20180348. http://dx.doi.org/10.1098/rsbl.2018.0348

# 5 Progress report on ToRs and workplan

## 5.1 Biomass and abundance estimates for sardine and anchovy in ICES sub-Areas 7, 8 and 9 derived from echo-integration and Daily Egg Production methods

### 5.1.1 Indices derived from acoustic surveys

#### 5.1.1.1 Spring acoustic surveys

Three acoustics surveys were undertaken in spring to assess the biomass of sardine and anchovy in the Atlantic waters of ICES areas 9 and 8 (**Fig. 5.2.1.1**). Additionally, information on other small pelagic fish distributions were also surveyed (**section 5.2.4.4**). The PELAGO survey, conducted by IPMA, in the Gulf of Cadiz and Portuguese waters, took place from 28th April to 30 May. The IEO survey, PELACUS, sampled the Galician and Cantabric waters between 25th March and 18th April. And PELGAS, the Ifremer survey, was carried out during the period 28th April to 1st June in the Bay of Biscay. Detailed survey reports are presented in annex 3. Their sampling schemes and timing are presented in **Figure 5.1.1.1.1.**

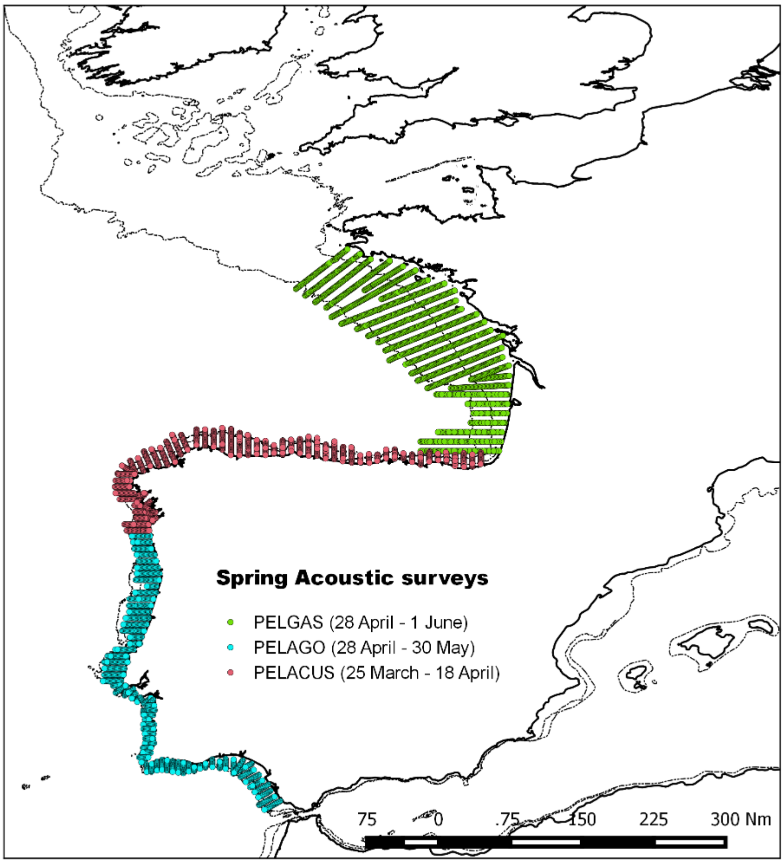



**Figure 5.1.1.1.1.: Sampling scheme and timings of the spring acoustic surveys 2018 in the ICES areas 8 and 9. PELAGO in blue, PELACUS in red and PELGAS in green.**

##### 5.1.1.1.1 Sardine and anchovy mean weight and length-at-age

Mean weight and length-at-age were calculated from the length and age abundance and biomass matrices estimated for each ICES Subdivision. Besides, for each age, a mean weight or length anomaly was calculated as the difference between the mean weight or length-at-age calculated in each ICES subdivision and the weighted average of weight or length calculated for the whole area. During spring 2018, the differences occurred in weight at age for all sardine age classes, especially from those sardines caught in 8ab compared with those from the southern part (8c and 9a) as shown in figures below.

###### 5.1.1.1.1.1 Subareas 8ab

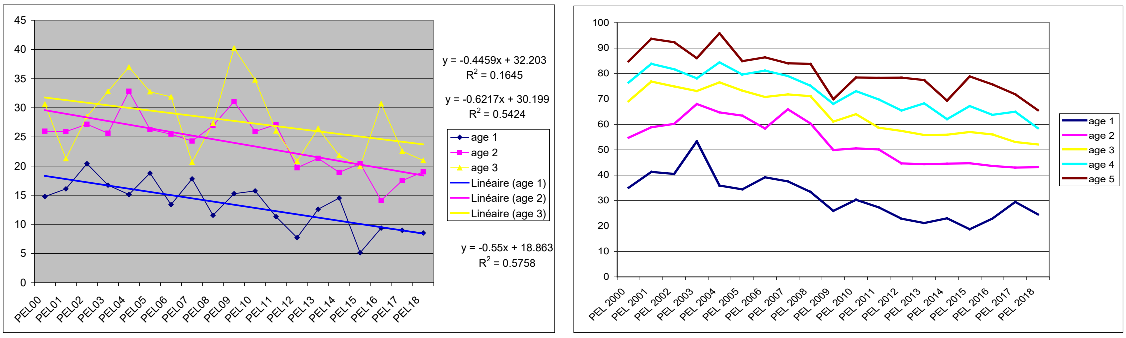



**Figure 5.1.1.1.1.1.1: Evolution of mean weight at age (g) of anchovy (left) and sardine (right) along Pelgas series.**

Figure **5.1.1.1.1.1.1** shows the evolution of mean weights at age for anchovy and sardine in the Bay of Biscay. As in previous years, we observe that globally the trend of the mean weight at age is a decrease for both species in the Bay of Biscay. This decreasing trend might be related to density-dependence and competition for food (Doray *et al.*, 2018). Further investigations are needed to confirm or reject this hypothesis.

###### 5.1.1.1.1.2 Subareas 8c and 9a

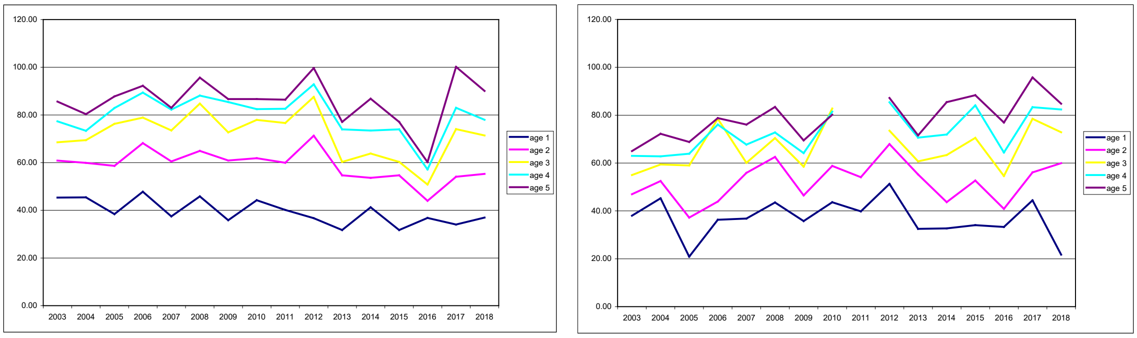



**Figure 5.1.1.1.1.2: evolution of mean weight at age (g) of sardine along PELACUS series in the 8c (left) and 9a (right).**

Maybe a light decrease in 8c in the mean weight at age occurred along the PELACUS series, particularly for the youngest individuals (ages 1 and 2), but further investigation would be done to know if it is statistically significant. In subarea 9a there is no clear trend about the evolution of the sardine mean weight at age since 2003.

### 5.1.1.1.2 Sardine and anchovy biomass and abundance estimates

#### 5.1.1.1.2.1. Subareas 8ab

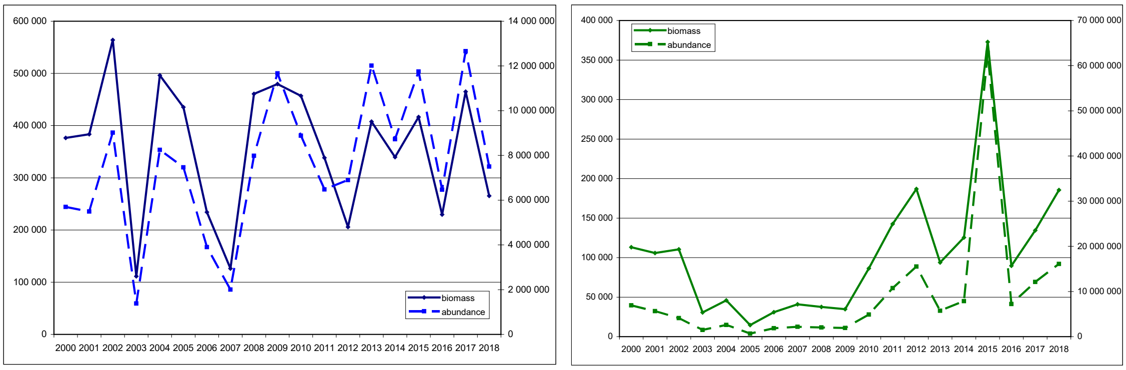



**Figure 5.1.1.1.2.1.1: Biomass and abundance trends for sardine (left) and anchovy (right) as observed during PELGAS survey in divisions 8ab**

The difference between trends for sardine could indicate that the mean length in the Bay of Biscay is decreasing (**Fig. 5.1.1.1.2.1.1**). Concerning anchovy in the Bay of Biscay, the biomass has been very contrasted since the beginning of the PELGAS series. During the first years (2000- 2003), the biomass has been at a medium level, then it became at a low or very low level due to the failure in 2005 that led to the fishery closure, waiting for a signal of recovery. It happened in 2010, thus the fishery re-opened and the biomass is at a high level since then (**Fig. 5.1.1.1.2.1.1**).

### 5.1.1.1.3 Subarea 8c and 9a North

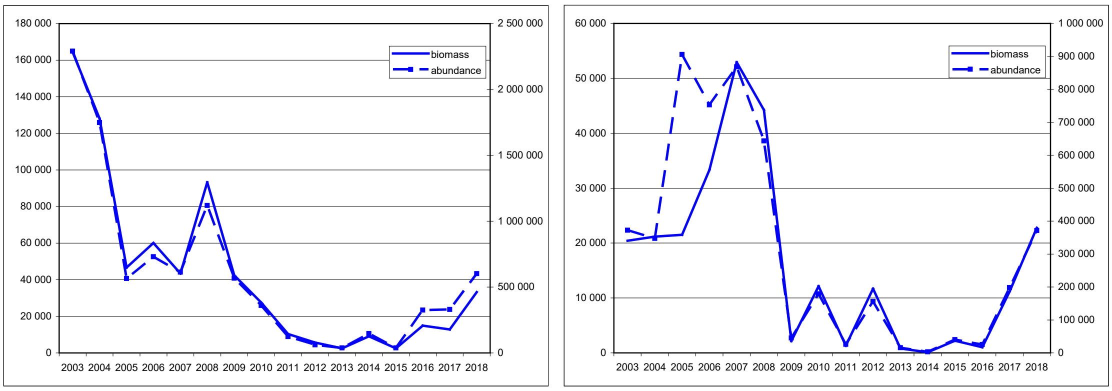



**Figure 5.1.1.1.2.2: sardine biomass and abundance trends as observed during PELACUS survey in division 8c (left) and 9a North right)**

For both areas 8c and 9a the signal is very strong for sardine, the trend of the biomass assessed by the PELACUS survey shows a clear failure, particularly marked between 2008 and 2009 in the South (division 9a). No sign of recovery could be detected until 2016-2017. This year, the trend is clearly an increase particularly in division 9a (Galician coastal waters). (**Fig. 5.1.1.1.2.2**).

#### 5.1.1.1.2.3. Subarea 9a West and South

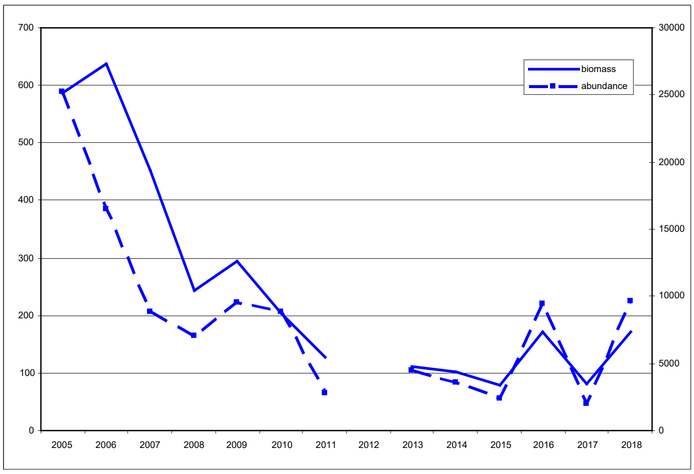



**Figure 5.1.1.1.2.3.1: Biomass and abundance trends for sardine as observed during PELAGO survey in subarea 9a West and South**

From Cadiz to the Northern frontier of Portugal, the sardine trend for both biomasses and abundances is clearly a decrease. At the beginning of the series, biomasses and abundances were high particularly in northern Portugal waters. Since 2011, no signal of recovery is detected. **Figure 5.1.1.1.2.3.1.**

### 5.1.1.2 Autumn acoustic surveys

The JUVENA (September 2003-2018) and PELTIC (October, 2015-2018) acoustic surveys provided a synoptic overview on the autumn distribution of small pelagic species and of their environment from the north Iberian coast in the south to the Celtic Sea in the north. The ECOCADIZ-RECLUTAS 2018-10 autumn acoustic survey provided the autumn distribution of small pelagic species and of their environment on the Gulf of Cadiz. (**Figure 5.1.1.2.1**).

The ECOCADIZ-RECLUTAS 2018-10 Spanish autumn acoustic survey was conducted by IEO between 10th and 29th October 2018 in the Portuguese and Spanish shelf waters off the Gulf of Cadiz onboard the R/V Ramón Margalef. No result from this survey has been provided to this WG because both acoustic data post-processing and the computation of the acoustic estimates are still in progress.

This year, IPMA and IEO have started a common acoustic-trawl survey called IBERAS-JUVESAR, aiming at estimating the strength of the sardine and anchovy recruitment and covering the Atlantic waters of the 9a (i.e. excluding the Gulf of Cádiz) (see annex 4 for details).

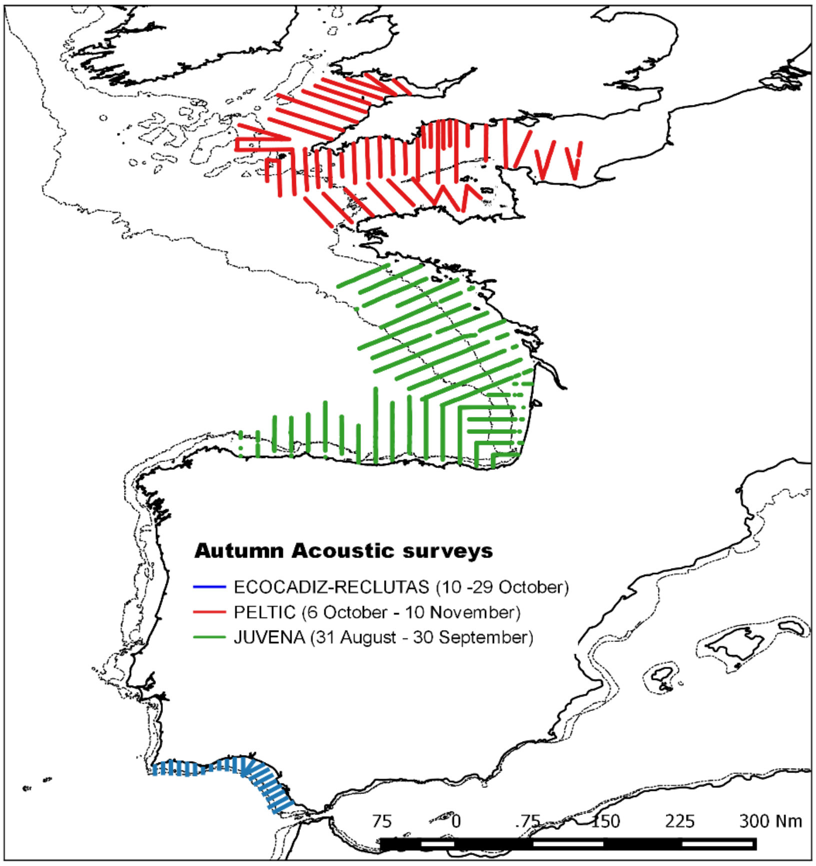



**Figure 5.1.1.2.1 Sampling scheme and timings of the autumn acoustic surveys 2018. ECO-CADIZ RECLUTAS in blue, PELTIC in red and JUVENA in green. Sardine and anchovy mean weight and length-at-age.**

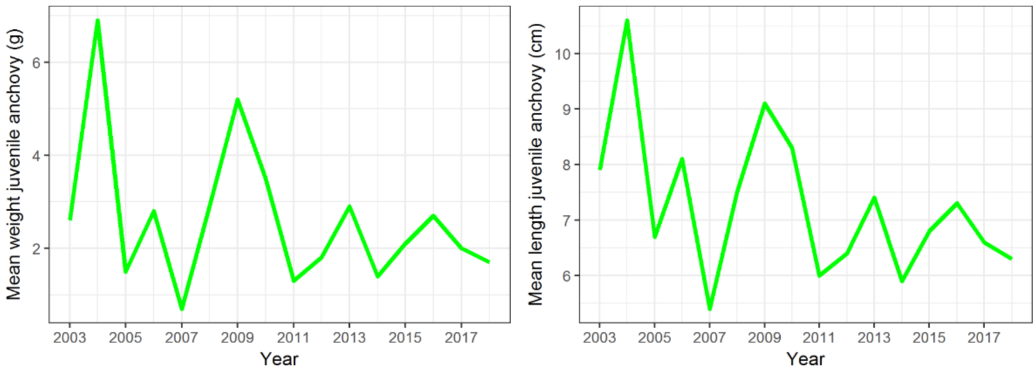



**Figure 5.1.1.2.1.1: evolution of mean weight (g) of juvenile anchovy (age 0) along JUVENA series Juvenile anchovy mean weight and length this year were lower than the series mean.**

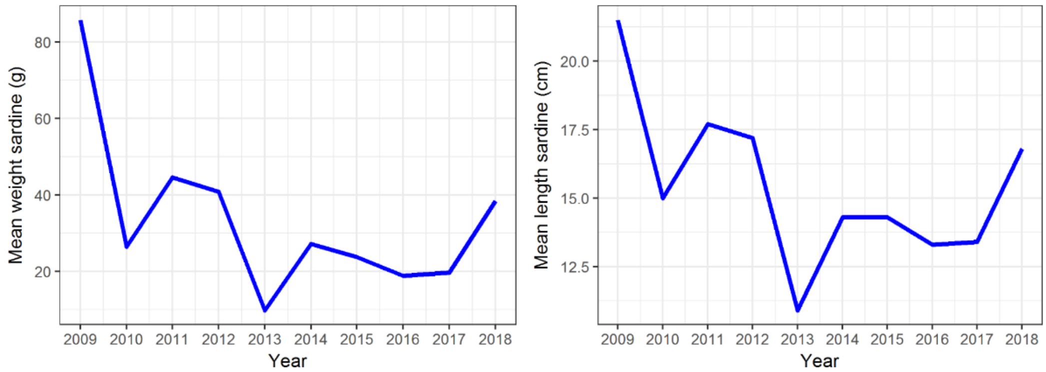



**Figure 5.1.1.2.1.2: evolution of mean weight (g) of sardine along JUVENA series.**

Sardine mean weight and length have increased in respect to the recent years.

#### 5.1.1.2.1 Sardine and anchovy biomass and abundance estimates

Juvenile anchovy biomass this year was about 70 % over the mean of the temporal series. Sardine biomass increased in 2018 compared with the last year and is now slightly above the average of the temporal series (**Fig. 5.1.1.2.2.1**)

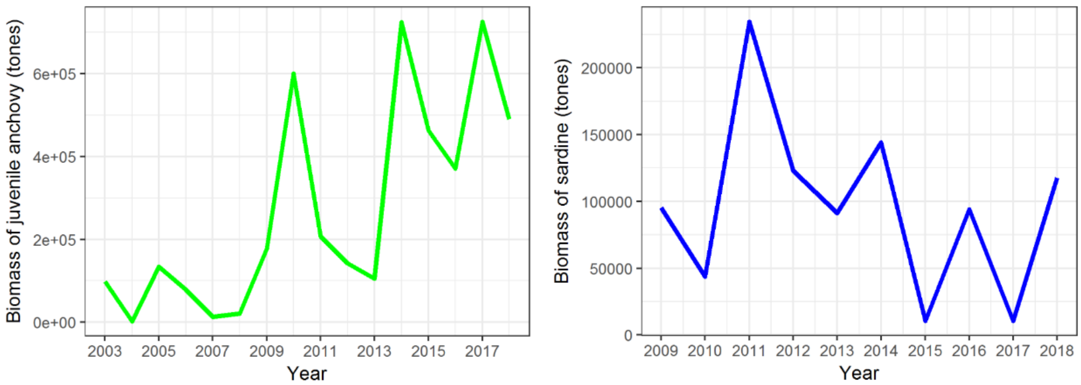



**Figure 5.1.1.2.2.1: evolution of autumn biomass of juvenile anchovy (age 0) (left) and sardine(right) in the Bay of Biscay collected during JUVENA series.**

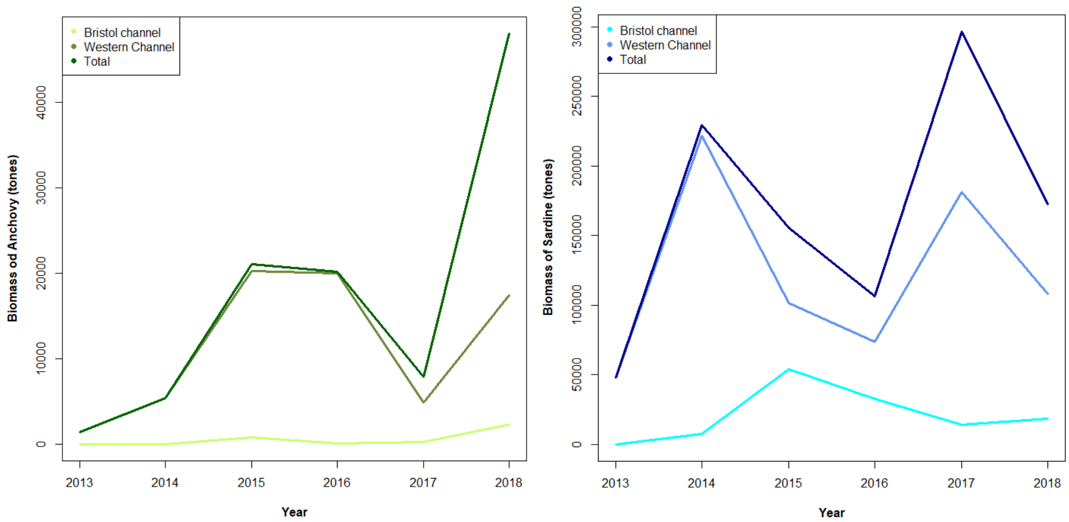



**Figure 5.1.1.2.2.2: Trend in autumn anchovy biomass (left) and sardine biomass (right) in the western Channel and Eastern Celtic Sea based on the PELTIC survey series. Please note that in 2017 and 2018 the survey coverage expanded and is included in the Total biomass.**

Anchovy biomass in the north of its distribution increased in 2018. A small but increasing contribution to the total biomass was found in the Bristol Channel (north of the Cornish Peninsula), whereas the biomass in the English Channel was comparable to those observed in 2015 and 2016. The strong increase in total biomass was caused largely by an increase in biomass around the isles of Scilly with further contributions from French waters and the eastern English Channel (**Fig. 5.1.1.2.2.2. left**).

Autumn sardine biomass in the north of its distribution slightly decreased in 2018 compared to 2017, although it was still above the average of the time series (**Fig. 5.1.1.2.2.2. right**).

### 5.1.1.3 Gulf of Cadiz summer acoustic surveys

The ECOCADIZ 2018-07 survey was carried out between 31st July and 13rd August 2018 onboard the R/V Miguel Oliver covering the Spanish and Portuguese waters of the Gulf of Cadiz, from Strait of Gibraltar to Cape San Vicente, between the 20 m and 200 m isobaths. The main objectives of this survey were the acoustic assessment and mapping of neritic fish resources and of the oceanographic and biological conditions off the Gulf of Cadiz continental shelf (**Fig. 5.1.1.3.1**).

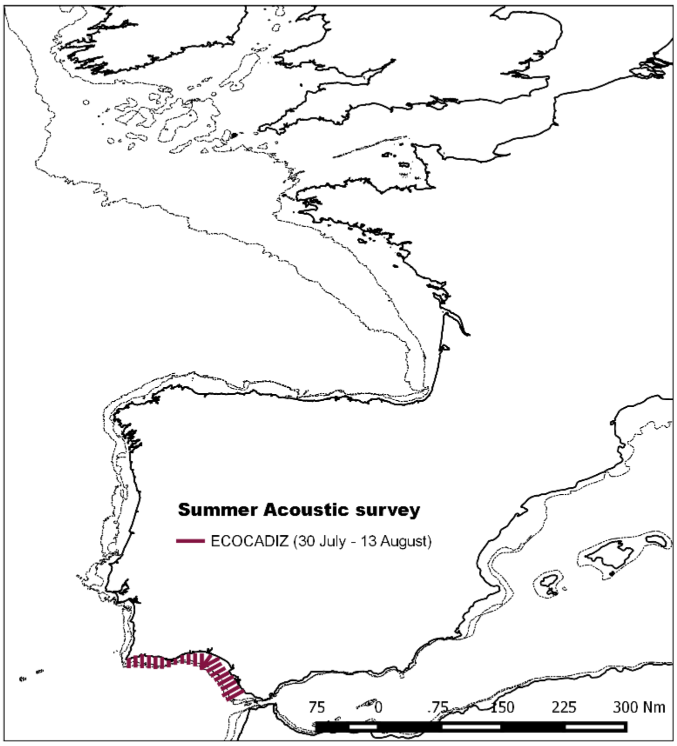
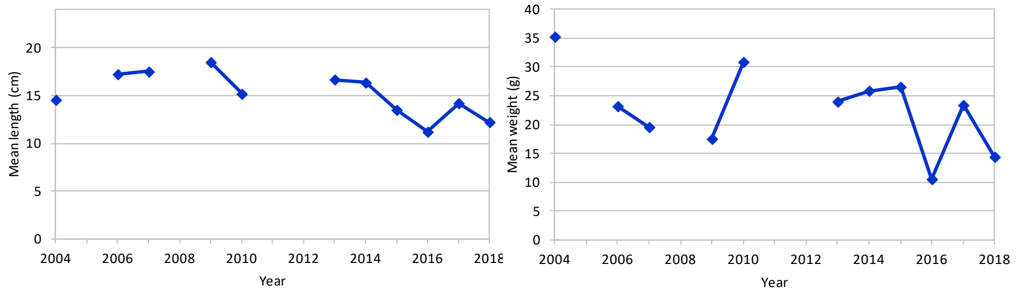



**Figure 5.1.1.3.1: Sampling scheme and timing of the summer acoustic survey ECOCADIZ in 2018.**

#### 5.1.1.3.1 Sardine and anchovy mean weight and length-at-age

**Sardine** mean weight and length-at-age in the assessed population are not available to this WG. Alternatively, **Figure 5.1.1.3.1.1** shows the mean length and weight along the time-series. The 2018 summer estimate of mean size and weight (122 mm, 14.4 g) are the second lowest ones within the series. This fact might be explained by the dominance of the juvenile/sub-adult fraction in the estimated population (main mode at 11.5

cm), which was mainly located in relatively shallow waters in front of Cape Santa Maria and in the coastal fringe comprised between El Rompido and the Guadalquivir river




mouth (see Ramos *et al*., 2018, WD in Annex 3).

**Figure 5.1.1.3.1.1: Sardine mean length and weight throughout the ECOCADIZ Gulf of Cadiz summer acoustic surveys series (gaps mean no survey).**

Concerning **anchovy,** the size class range of the assessed population varied between 9.0 and 17.0 cm size classes, with modal class at 12.0 cm. The size composition of anchovy by coherent size-based post-strata confirms the usual pattern exhibited by the species in the area during the survey season, with the largest (and oldest) fish being distributed both in the westernmost and easternmost waters off the Gulf and the smallest (and youngest) ones concentrated in the surroundings of the Guadalquivir river mouth and adjacent shallow waters, including those ones in front of the Bay of Cadiz (see Ramos *et al*., 2018, WD in Annex 3). As it has been happening over the last years, during the 2018 survey some recruitment has also been recorded, probably because of the delayed survey dates. This fact is reflected in the estimated mean size and weight of the whole population because the lower mean length and weight estimated for the whole estimated population (120 mm; 11.4 g) in relation with the historical mean values (124 mm, 13.0 g; **Fig. 5.1.1.3.1.2**).

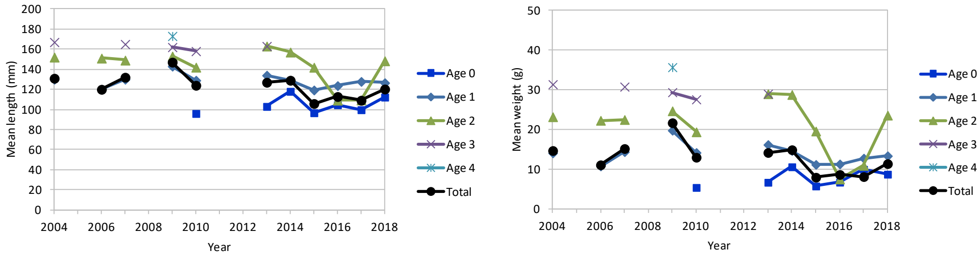



**Figure 5.1.1.3.1.2: Sardine mean length and weight throughout the ECOCADIZ Gulf of Cadiz summer acoustic surveys series (gaps mean no survey).**

### 5.1.1.3.2 Sardine and anchovy biomass and abundance estimates

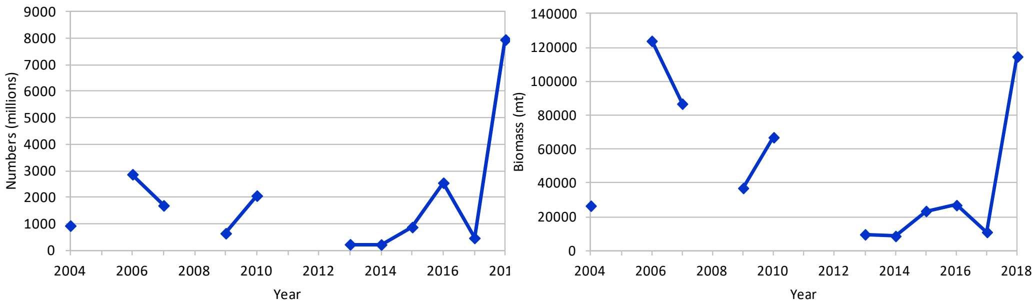



**Figure 5.1.1.3.2.1: Sardine abundance (million fish) (left) and biomass (t)(right) estimates through the ECOCADIZ Gulf of Cadiz summer acoustic surveys series (gaps mean no survey).**

The estimates of Gulf of Cadiz sardine abundance and biomass in summer 2018 were 7 955 million fish and 114 631 t, the historical maximum record in terms of abundance and the second maximum in biomass (the historical maximum was reached in 2006: 123 849 t; **Figure 5.1.1.3.2.1**). Spanish waters concentrated the bulk of the population (7 239 million and 90 214 t). The estimates for the Portuguese waters were 716 million and 24 417 t.

The PELAGO 18 spring Portuguese survey previously estimated for this same area 58 561 t (6 680 million): 22 627 t (1 097 million) in Portuguese waters and 35 934 t (5 583 million) in Spanish waters.

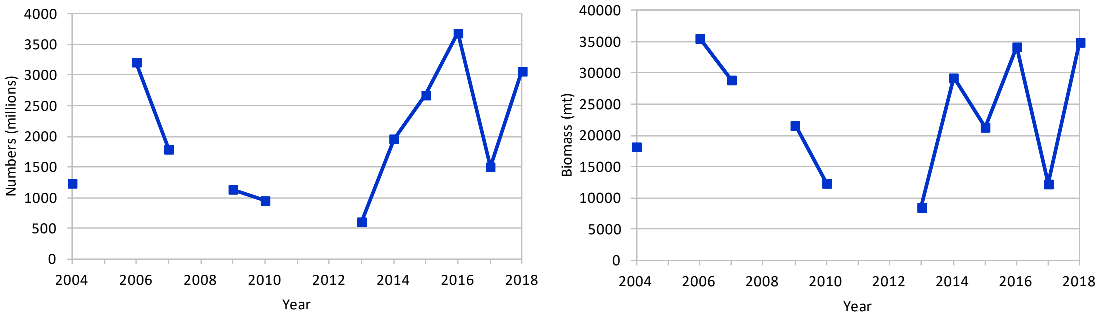



**Figure 5.1.1.3.2.2: Anchovy abundance (million fish) and biomass (t) estimates through the ECOCADIZ Gulf of Cadiz summer acoustic surveys series (gaps mean no survey).**

Gulf of Cadiz anchovy acoustic estimates in summer 2018 were of 3 063 million fish and 34 908 tones. By (country) geographical strata, the Spanish waters yielded 93% (2 839 million) and 88% (30 683 t) of the total estimated abundance and biomass in the Gulf, confirming the importance of these waters in the species' distribution. The estimates for the Portuguese waters were 224 million and 4 225 t.

The current biomass estimate (34 908 t) becomes in the second historical maximum within the time-series (2006: 35 539 t; 2016: 34 184 t; **Fig. 5.1.1.3.2.2**).

The *PELAGO 18* spring Portuguese survey previously estimated for this same area 23 473 t (2 157 million): 4 328 t (300 million) in Portuguese waters and 19 145 t (1 857 million) in Spanish waters.

### 5.1.2 Indices derived from DEPM surveys

This year the only DEPM survey that was carried out was the BIOMAN survey that is conducted every year, the other DEPM surveys are conducted each three years. The DEPM survey BIOMAN targeting anchovy and sardine for the Bay of Biscay (ICES divisions 8abcd) was conducted by AZTI during May every year since 1987. It covers the Bay of Biscay, ICES areas 8abcd (**Fig. 5.1.2.1).**

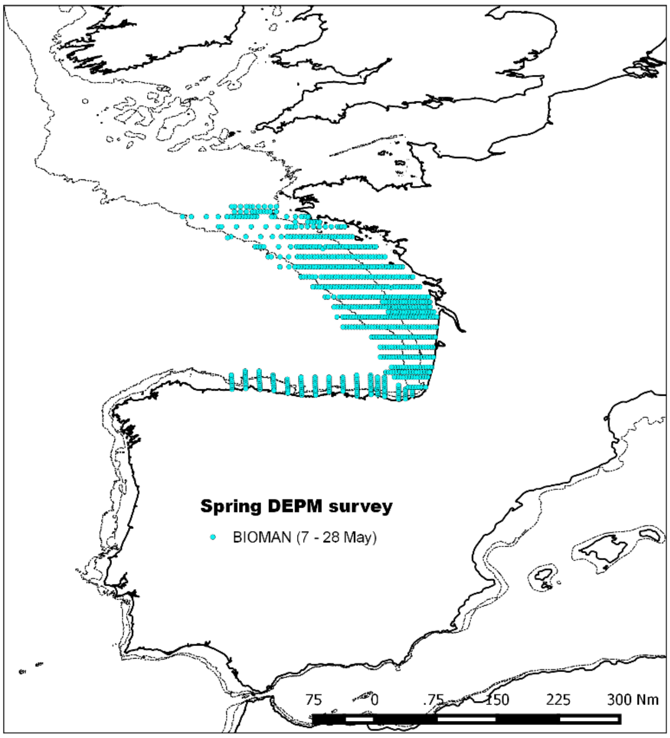



**Figure 5.1.2.1: Sampling scheme and timing of the spring DEPM survey BIOMAN 2018.**

### 5.1.2.1 Egg parameters estimates

The DEPM BIOMAN survey has produced egg parameter estimates for anchovy in ICES areas 8abcd (Time series is showed in **Figure 5.1.2.1.1**) and egg abundance for sardine in areas 8abd and 8abcd (**Fig. 5.1.2.1.2**)

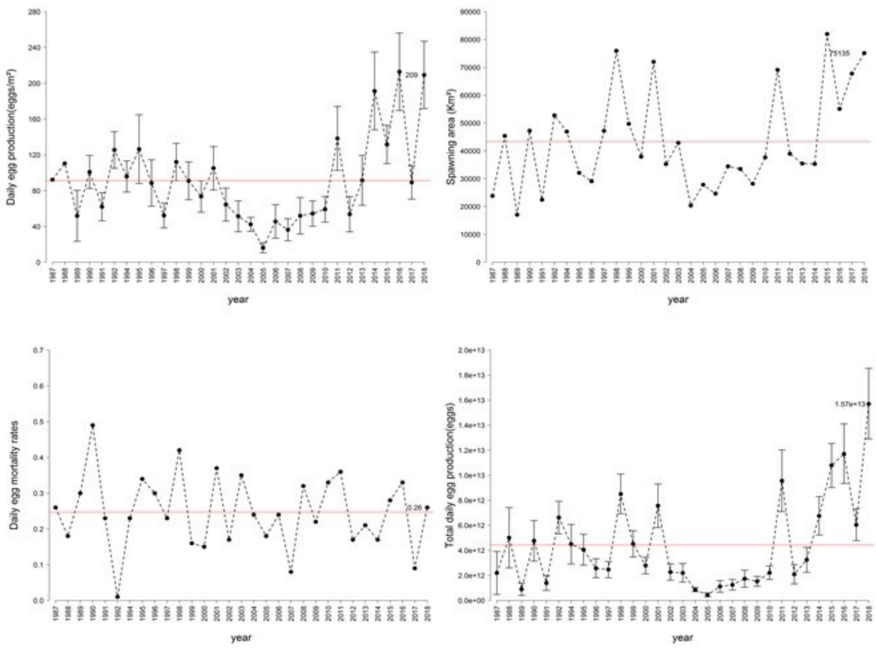



**Figure 5.1.2.1.1: historical series and 2018 estimates of daily egg production ($P_0$) (egg/m²/day), spawning area (Km²), daily mortality rates (z) and total daily egg production ($P_{tot}$)(eggs/day) as the product between spawning area (SA) and daily egg production ($P_0$) estimates with its CV for anchovy in the Bay of Biscay. Red line is the mean and the value of the actual year is showed.**

In 2018 daily egg production($P_0$) (209egg/m$^2$) was higher than the mean (91.18 egg/m$^2$ cv:9%) and at the levels of last year that was the highest of the historical series. The spawning area (75,135 Km$^2$) was higher than the mean (43,330 Km$^2$) and higher than the last two years. The daily mortality rates (z) (0.26 cv:17%) was at level of the mean (0.25), the z value of this year means that 23% of the eggs were dying per day. Total daily egg production ($P_{tot}$) (1.57e+13eggs cv:9%) was higher than the mean (4.43e+12eggs) and the highest of the historical series.

Sardine total egg abundance series from BIOMAN survey is showed in **figure 5.1.2.1.2**(is the sum of the egg abundance in each station multiplied by the area each station represent). These values were used as an index in the assessment for sardine in Divisions 8abd.The Northwest part surveyed in some years was removed to have the same area surveyed each year and be coherent within the historical series. In the figure is showed the total egg abundance in all the area surveyed and in the 8abd with the Northwest part, as well.

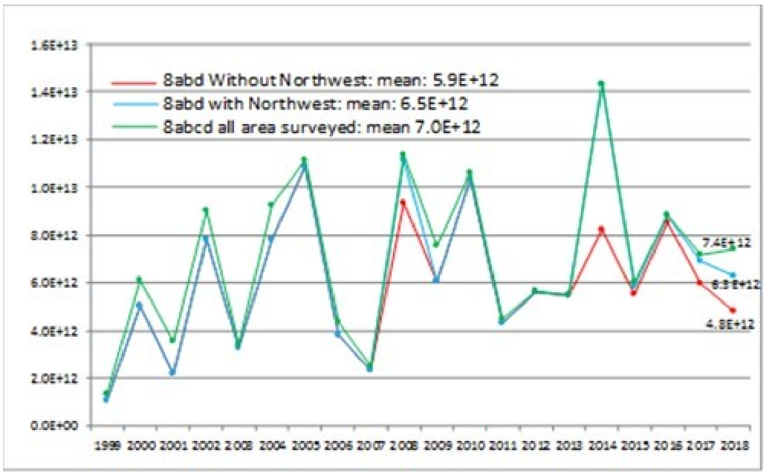



**Figure 5.1.2.1.2: historical series and 2018 estimates of sardine total egg abundances (eggs)in all the area surveyed 8abcd (green line), in 8abd (blue line) and in 8abd without the north-west part (red line) for assessment proposes to be consistent with the historical series.**

### 5.1.2.2 Reproductive parameters and total anchovy biomass estimates

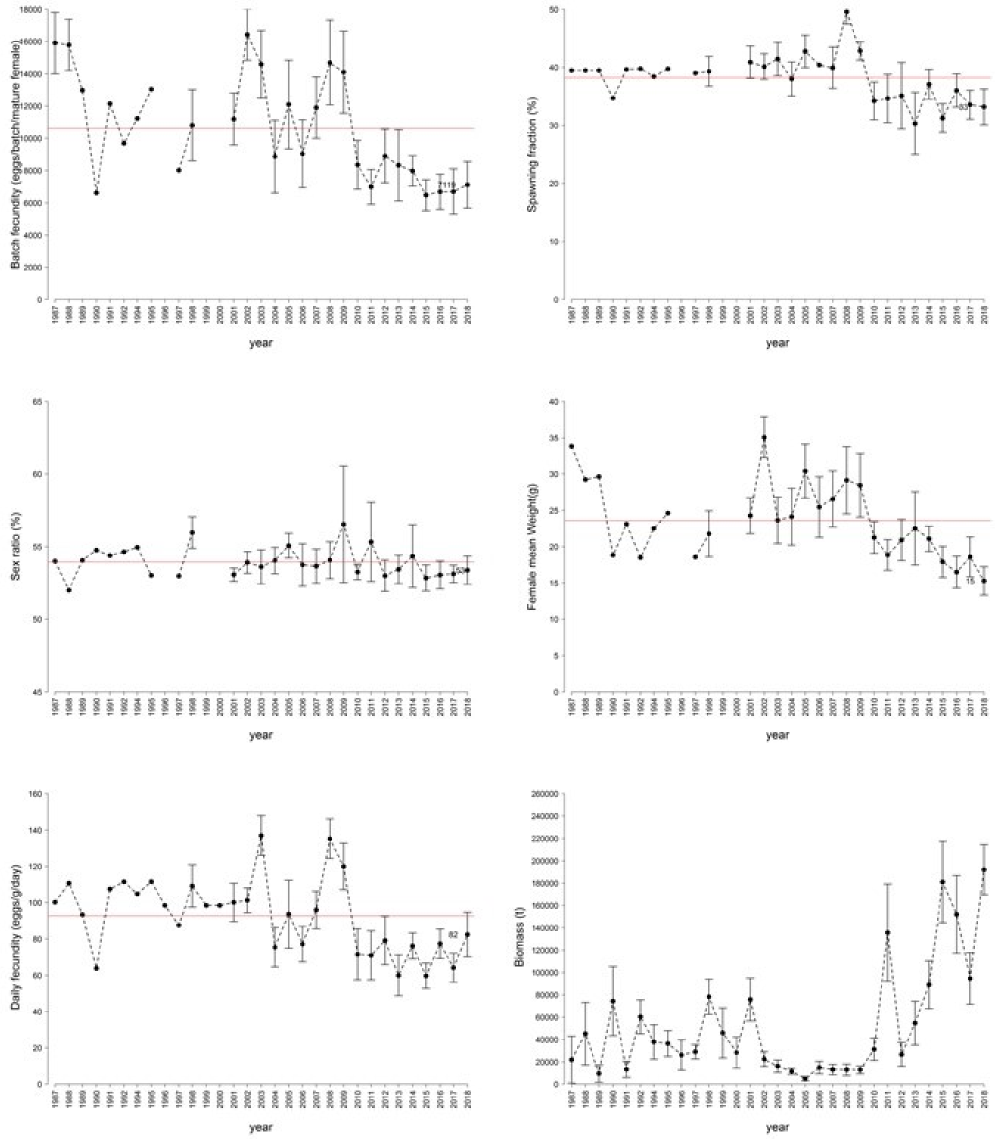



**Figure 5.1.2.2.1 historical series including 2018 estimates of the adult parameters from the DEPM for anchovy in the Bay of Biscay (ICES 8abcd) batch fecundity (eggs/batch/mature female), spawning fraction (% of females spawning per day), sex ratio (% of females), females mean weight(g), daily fecundity (eggs/g/day) and the total biomass(tons).**

The batch fecundity this year (7,119eggs/batch/mature female) is higher than the last 3 years but since 2010, after the open of the fishery after 5 years of fishery closure, the tendency was maintained lower than the mean. The spawning frequency this year is 33% at levels of last year but since 2010 was maintained around 35%, lower than the tendency before the aperture in 2010. The sex ratio (53% cv:0.9%) did not change much in the time series that is around 50%. The female mean weight (15.29g cv: 6%) is lower than last year and the general tendency in the historical series is downward and specially after 2010 that was down drastically. The daily fecundity (82.5egg/g/day cv:7%) since 2010, the year of the reopening of the fishery, was going up and down, but maintained around 70 eggs/g/day, and the biomass this year is the highest of the historical series (**Fig. 5.1.2.2.1**).

### 5.1.2.3 Weight, length, numbers, percentage and biomass-at-age estimates

Mean weight (**Fig. 5.1.2.3.1**) and length-at-age were calculated from the historical series of BIOMAN surveys. A notable decrease since the beginning of this century in the weight is observed specially for age 1 and 2 and specially since 2010, when the fishery was open after 5 years of closure.

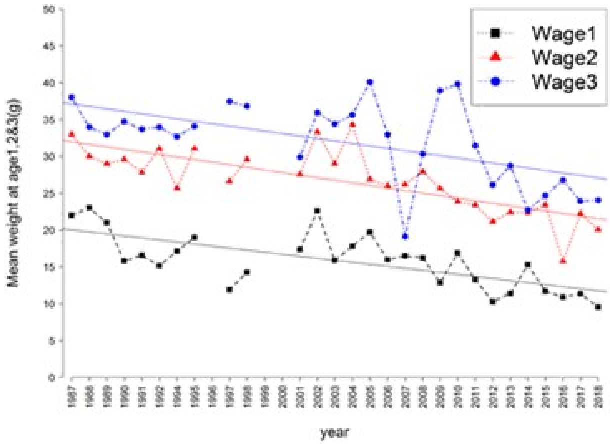



**Figure 5.1.2.3.1 historical series and 2018 estimates of anchovy mean weight (grams) at age in the Bay of Biscay observed during BIOMAN surveys. W at age 1(black), W at age 2(red)and W at age 3 (blue).**

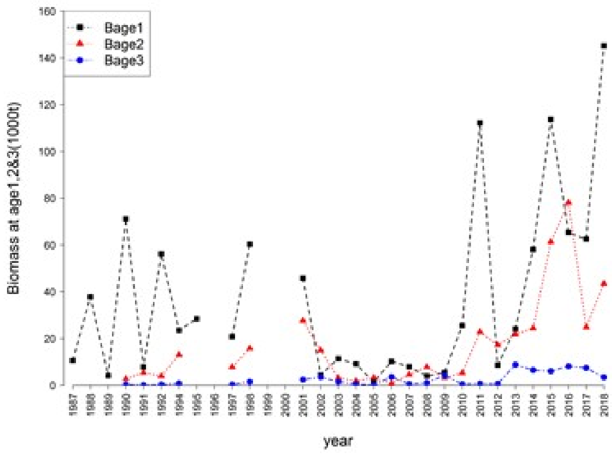



**Figure 5.1.2.3.2 historical series and 2018 estimates of biomass(tones) at age 1(black), age 2 (red) and age 3(blue) for anchovy in the Bay of Biscay observed during BIOMAN surveys.**

Between 1987 and 2001 the anchovy biomass derived from the DEPM were below 80,000t (**Fig. 5.1.2.3.2**). During this period the biomass was changing up and down from one year to the other. From 2002 to 2009 DEPM SSB estimates were below 20 000 t. Within this period the fishery had difficulties to get normal levels of catches. In 2003 there was a deep crisis of the Spanish fishery (STECF 2003) and later in 2005 and 2006 the Spanish fishery crashed and was unable to get any significant catch. This led to the repeated closure of the fishery first in June 2005 and next in June 2006 which last until January 2010. The DEPM estimated a recovery of the population in 2010 and peaked in 2011 and 2015. This year 2018 was the historical maximum with 192,088t cv 12%. In 2010 and 2011 the recovery was due to a strong recruitment, as reflected in the high percentage of 1-year old anchovies (above 85%, **Fig. 5.1.2.3.3**). This year the percentage of 1 year old in numbers was 87%, reflecting a good recruitment as well. In mass it was 76%. More information is showed in the **wd Santos *et al* 2018 in annex 3.**

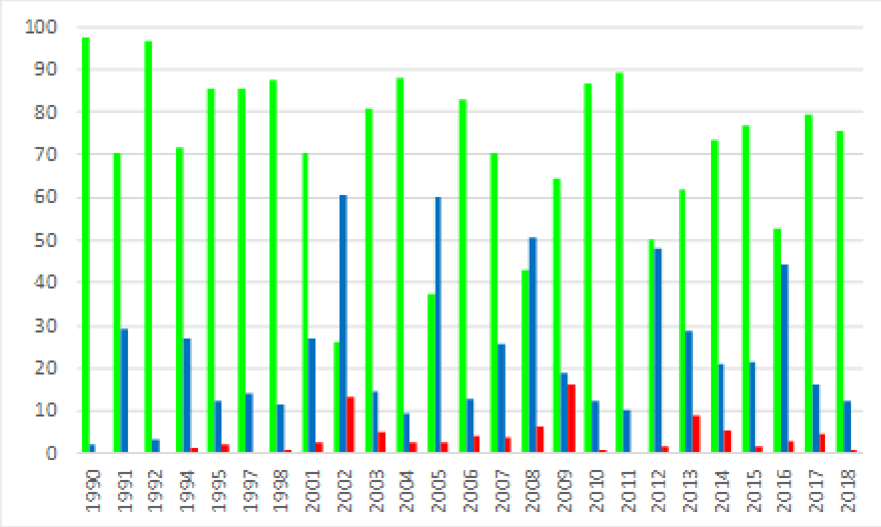



**Figure 5.1.2.3.3 historical series and 2018 estimates of percentage at age 1(green), age 2 (blue) and age 3(red) for anchovy in the Bay of Biscay observed during BIOMAN surveys.**

## 5.2 Distribution of eggs and adult of small pelagic fish in their environment in ICES sub-areas 7, 8 an 9

### 5.2.1 Spring acoustic surveys

#### 5.2.1.1 Oceanographic conditions

The coordinated spring acoustic surveys were conducted between the 27th March and June 1st. The southern region, sampled by PELAGO, and the northern area, surveyed during PELGAS, were covered roughly during the same period whereas the PELACUS survey, in the intermediate region, was finalized a couple of weeks before the other two started. Consequently, the joint, apparently, synoptic map for sea surface temperature and salinity should be regarded with that in mind. As usual, the warmer waters appeared in the southern coast, where the temperatures varied between 17ºC, in the western shore, and 20 ºC towards the eastern Cadiz Bay. The colder sea surface temperatures (13-16 ºC) were observed in the Cantabrian Sea and also in some areas under the influence of river outflow, off NW Portugal and W Galicia and in the Bay of Biscay. In these regions close to important rivers, the presence of water from continental origin was also apparent in the surface salinity distribution (**Fig. 5.2.1.1.1**). Overall, the water temperature during the 2018 spring surveys was within the same range as in previous years although slightly lower than in 2017 while the salinity distribution observed during the 2018 surveys showed clear evidences of the fairly rainy, late winter-early spring, period which occurred in the Atlantic façade prior to the surveys.

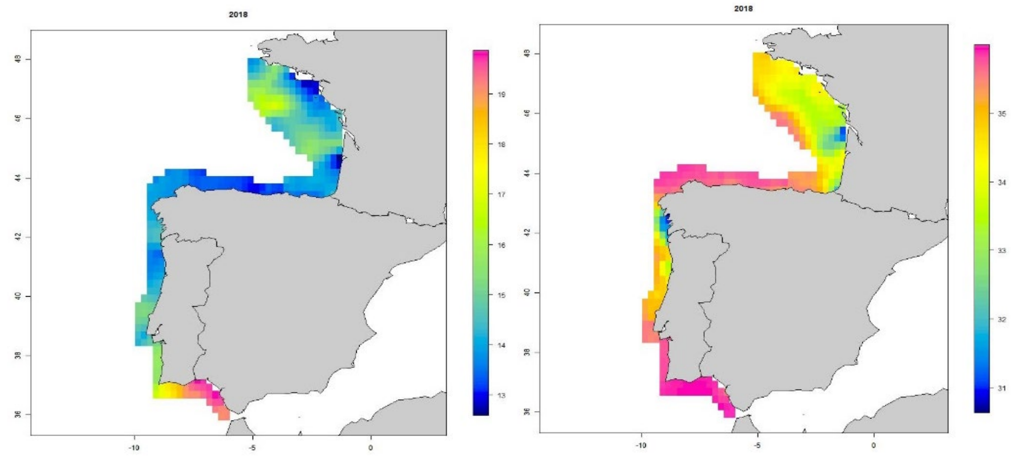



**Figure 5.2.1.1.1: Sea surface temperature (left) and salinity (right) during the 2018 spring acoustics surveys (PELAGO, PELACUS, PELGAS) in the period March-May 2018. For dates of coverage in each region and other details see figure 5.1.1.1.1 and annex 3.**

### 5.2.1.2 Trawl haul catch composition

Although fishing hauls are normally conducted to provide ground-truth to the echotraces recorded by the echosounders and to estimate the age/length spatial distribution by species along the surveyed area, thus done in an opportunistic way, they will reflect the abundance of the main pelagic fish species related to the echotraces. **Figure 5.2.1.2.1**. shows the percentage (in weight) of the fishing stations done during the spring acoustic surveys.

Mackerel was the most dominant species on the Spanish continental shelf. Complementary, blue whiting was also abundant near the slope. Along the Portuguese coast, anchovy was clearly dominant in the northern part, while sardine appeared in the catches realised in the southern part (but in lower quantities according to small echotraces). In French waters the same patterns would also inferred with anchovy being for mostly present around the Gironde mouth and along the southern part of the continental shelf, while sardine occurrence was higher in the coastal waters in the South and around the Loire mouth.

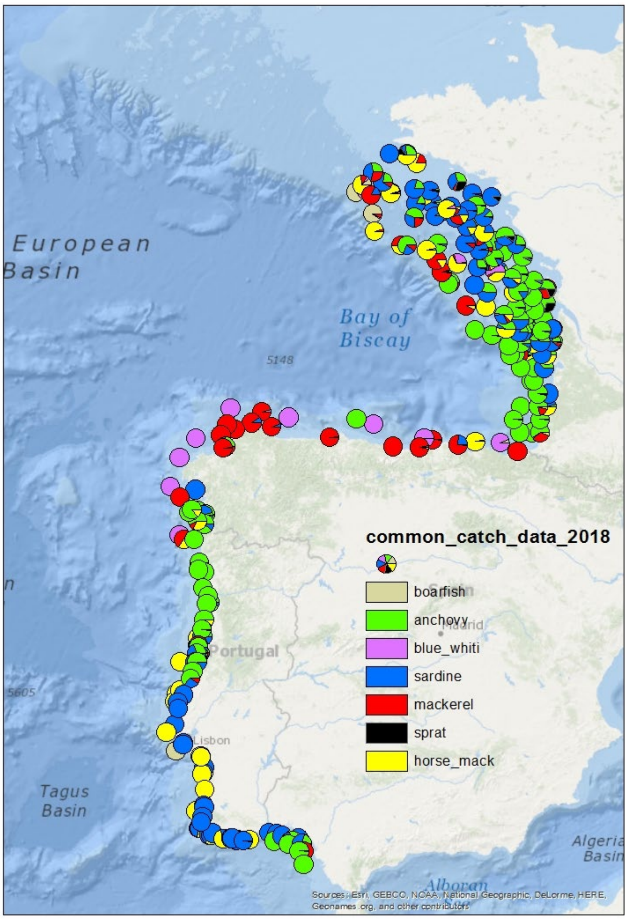



**Figure 5.2.1.2.1 trawl haul catch composition during spring acoustic surveys.**

### 5.2.1.3 Adult sardine and anchovy acoustic density (NASC) distribution

#### 5.2.1.3.1 Adult anchovy acoustic density (NASC) distribution

From 2003 to 2018, adult anchovy core distribution areas in springtime were, by decreasing order of importance: coastal areas in Southern Bay of Biscay (Gironde and Landes coast, ~46°N), the Gulf of Cadiz (~37°N) (Fig. 5.2.1.3.1). In 2018, anchovy concentrations displaying above average densities were observed in the species core distribution areas, and North of Cape Mondego on the Western coast of Portugal (~40-42°N), in an area where denser anchovy concentrations have appeared since 2015 (Fig. 5.2.1.3.2).

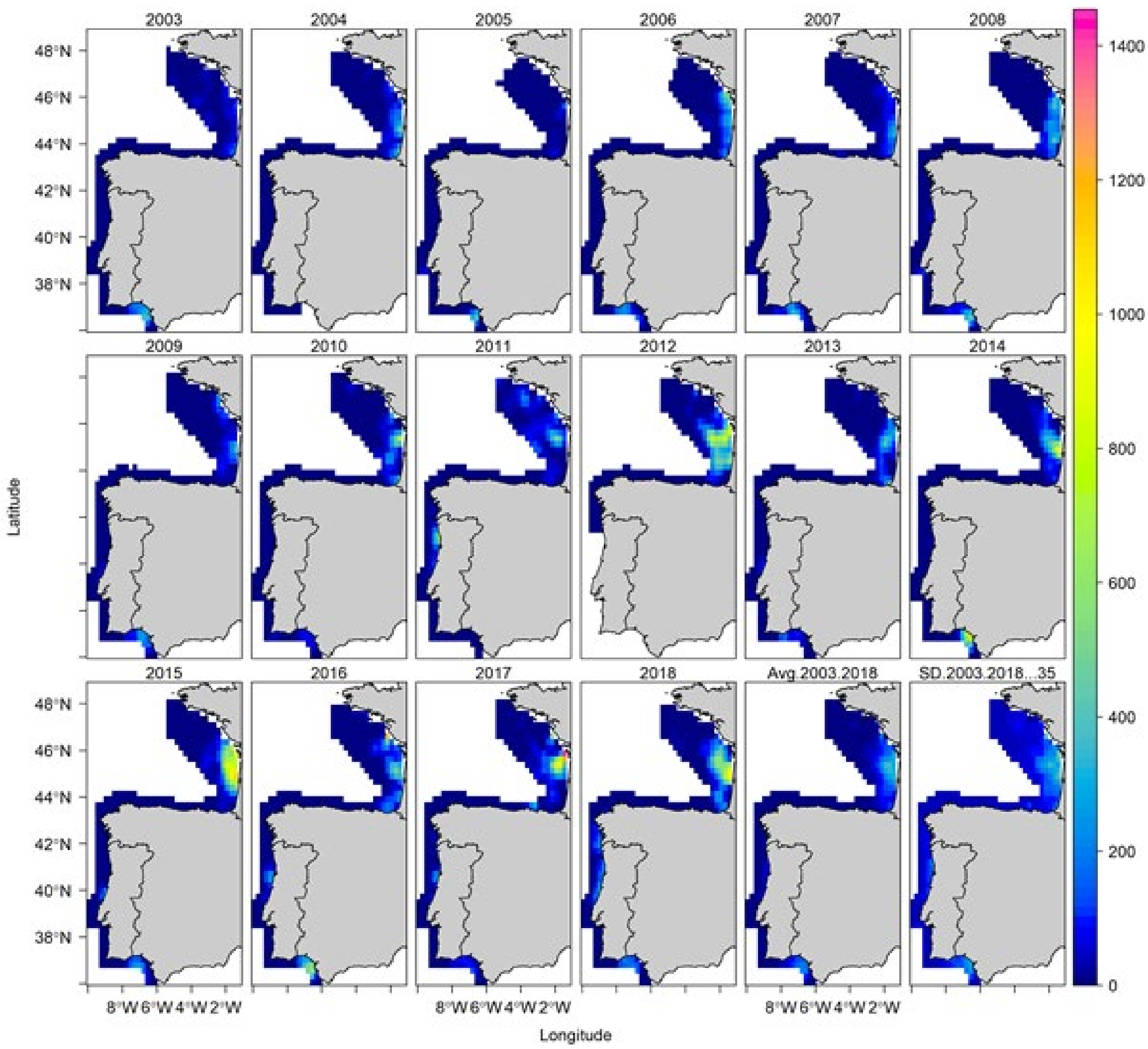



**Figure 5.2.1.3.1 Adult anchovy mean acoustic density (NASC, m².NM-²) maps derived from the PELAGO, PELACUS and PELGAS surveys, 2003-2018, 0.25° map cell. "Avg.2003-2018 pane": map of anchovy NASC values averaged over the series. "SD.2003-2018 pane": map of anchovy NASC standard deviation over the series.**

**Figure 5.2.1.3.2: Maps of adult mean anchovy acoustic density (NASC, $m^2.NM^{-2}$) anomalies derived from the PELAGO, PELACUS and PELGAS surveys, 2003-2018. Anomalies have been calculated by subtracting the mean map from annual maps. Grid dimensions: 0.25°.**

From 2003 to 2018, sardine core distribution areas in springtime were, by decreasing order of importance: the coastal areas of the Bay of Biscay, the Western Portuguese coast, and the Gulf of Cadiz (~37°N) (**Fig. 5.2.1.3.2.1**). In 2018, sardine densities were higher than average in coastal areas in the Southern Bay of Biscay, in South-western Brittany (~48°N), North of Cape Mondego on the Western coast of Portugal and in the Gulf of Cadiz. Lower than average sardine densities were found in Northern Portugal and Galicia, as well as in coastal areas between Loire and Garonne rivers (**Fig. 5.2.1.3.2.2**).

#### 5.2.1.3.2 Adult sardine acoustic density (NASC) distribution

**Figure 5.2.1.3.2.1: Adult sardine mean acoustic density (NASC, $m^2.NM^{-2}$) maps derived from the PELAGO, PELACUS and PELGAS surveys, 2003-2017, 0.25° map cell. "Avg.2003-2018 pane": map of sardine NASC values averaged over the series. "SD.2013-2018 pane": map of sardine NASC standard deviation over the series.**

**Figure 5.2.1.3.2.2: Maps of adult mean sardine acoustic density (NASC, $m^2.NM^{-2}$) anomalies derived from the PELAGO, PELACUS and PELGAS surveys, 2003-2018. Anomalies have been calculated by subtracting the mean map from annual maps. Grid dimensions: 0.25°.**

### 5.2.1.4 Other adult small pelagic fish species acoustic density distributions

Boarfish (*Capros aper*) has been occasionally observed during the PELGAS and PELACUS spring acoustic since 2003 (**Fig. 5.2.1.4 1**). It appeared to be distributed in offshore areas and was only marginally sampled by the small pelagic surveys focusing on the continental shelf. The highest concentrations of boarfish were observed in the Western end of the Cantabrian area in 2014. Few boarfish have been observed in North-Western Biscay in 2018.

**Figure 5.2.1.4.1: Boarfish (*Capros aper*) acoustic density (NASC, m$^2$.NM$^{-2}$) maps derived from the PELACUS and PELGAS surveys, 2003-2018, 0.25° map cell. "Avg.2003-2018 pane": map of NASC values averaged over the series. "SD.2003-2018 pane": map of NASC standard deviation.**

High concentrations of blue whiting (*Micromesistius poutassou*) have been consistently observed during the springtime acoustic surveys in the Cantabrian Sea since 2013. Secondary distribution areas were also located over the continental shelf in the North Western Bay of Biscay (**Fig. 5.2.1.4 2**). In 2018, significant concentrations of blue whiting were observed only in the Cantabrian Sea.

**Figure 5.2.1.4.2: Blue whiting (*Micromesistius poutassou*) acoustic density (NASC, $m^2.NM^{-2}$) maps derived from the PELACUS and PELGAS surveys, 2003-2018, 0.25° map cell. "Avg.2003-2018 pane": map of NASC values averaged over the series. "SD.2003-2018 pane": map of NASC standard deviation.**

Dense concentrations of chub mackerel (*Scomber colias*) have been observed in springtime mostly in Southern Portugal and marginally in the Southern part of the Bay of Biscay since 2003. Low densities of chub mackerel have been observed essentially in Southern Biscay in 2018. (**Fig.5.2.1.4.3**).

**Figure 5.2.1.4.3: Chub mackerel (*Scomber colias*) acoustic density (NASC, $m^2.NM^{-2}$) maps derived from the PELACUS and PELGAS surveys, 2003-2018, 0.25° map cell. "Avg.2003-2018 pane": map of NASC values aver-aged over the series. "SD.2003-2018 pane": map of NASC standard deviation.**

Atlantic mackerel (*Scomber scombrus*) has been essentially observed in the Central Cantabrian area, and along the coasts of Brittany and Vendée (46-48°N) and near the shelfbreak (46°N) in the Bay of Biscay since 2003 in springtime. It was essentially found in Western Cantabrian and Southern Biscay areas in 2018 (**Fig. 5.2.1.4.4**).

**Figure 5.2.1.4.4: Atlantic mackerel (*Scomber scombrus)* acoustic density (NASC, m².NM-²) maps derived from the PELACUS and PELGAS surveys, 2003-2018, 0.25° map cell. "Avg.2003-2018 pane": map of NASC values aver-aged over the series. "SD.2003-2018 pane": map of NASC standard deviation.**

Mediterranean horse mackerel (*Trachurus mediterraneus*) has been mostly observed in springtime along the Landes coast in the Bay of Biscay (~44°N) since 2003. Small secondary concentrations of this species were also observed in the centre of the Bay of Biscay platform (~46°N) and in the Central Cantabrian area (4°W). In 2018, unusual high-density concentrations of Mediterranean horse mackerel were found in the North-Western part of the Bay of Biscay. Smaller patches of this species were also observed in Southern Biscay (**Fig. 5.2.1.4.5**).

**Figure 5.2.1.4.5: Mediterranean horse mackerel (*Trachurus mediterraneus*) has been mostly observed in springtime along the Landes coast in the Bay of Biscay (~44°N) since 2003. Small secondary concentrations of this species were also observed in the centre of the Bay of Biscay platform (~46°N) and in the Central Cantabrian area (4°W). In 2018, unusual high-density concentrations of Mediterranean horse mackerel were found in the North-Western part of the Bay of Biscay. Smaller patches of this species were also observed in Southern Biscay.**

**Figure 5.2.1.4.6: Horse mackerel (*Trachurus trachurus*) acoustic density (NASC, $m^2.NM^{-2}$) maps derived from the PELACUS and PELGAS surveys, 2003-2018, 0.25° map cell. "Avg.2003-2018 pane": map of NASC values averaged over the series. "SD.2003-2018 pane": map of NASC standard deviation.**

Horse mackerel (*Trachurus trachurus*) has been consistently observed at low density along the shelf break and in southern part of the Bay of Biscay (**Fig 5.2.1.4 6**). In 2018, horse mackerel was essentially found in the Southern Bay of Biscay Western area.

New gridded maps have been produced by combining data collected in 2018 during the spring acoustic surveys (PELAGO, PELACUS, PELGAS and WESPAS) on boarfish, horse mackerel, sprat and blue whiting. These maps provide a unique synoptic overview of the distribution of those species in the European Atlantic Area from Spain to UK (cf. **Annex 5.2.1.4**).

#### 5.2.1.5 Sardine and anchovy egg distributions from CUFES sampling

The sardine and anchovy egg distribution patterns derived from the CUFES observations, during the spring acoustics surveys in 2018 (PELAGO, PELACUS, PELGAS) are shown in **figure 5.2.1.5.1.** Globally, more anchovy eggs were collected than sardine eggs. This trend was already noticed in the recent past, but it was very evident in 2018, when record numbers of anchovy eggs were observed in the more southern areas. In fact, during the 2018 spring surveys more anchovy eggs were collected off NW Portugal than in the Bay of Biscay, where usually the abundances were higher. This result may be partially explained by the delay in the Portuguese survey, which has occurred more into the anchovy spawning season (and later in the sardine reproductive period) in the latest years but it is mainly a consequence of the considerable increase of the anchovy population over the entire NW Portuguese shelf (see also **section 5.2.1.3**).

Although in much lower numbers than the anchovy eggs, the sardine egg densities were higher in 2018 than in 2017, with two clear denser spots off the Portuguese coast, the more southern, just to the south of Cape Carvoeiro (north of Lisbon) and another one over the NW shelf close to Douro river mouth. In the central Bay of Biscay patches of higher sardine egg abundances were also observed but those were weaker in the 2018 spring than during the 2017 survey. More details on the egg abundances distributions can be found in the survey reports in **annex 3.**

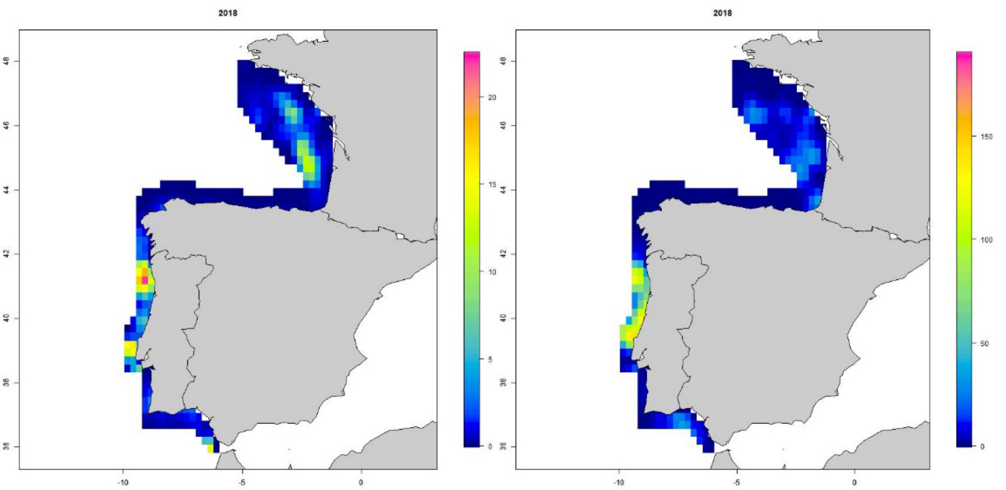



**Figure 5.2.1.5.1: Sardine (left) and anchovy (right) egg distributions from CUFES (eggs/m3) observations during the 2018 spring acoustics surveys (PELAGO, PELACUS and PELGAS). For dates of coverage in each region see figure 5.1.1.2.1 and annex 3. Note that due to the data range in the observations the colour scales do not match between panels.**

### 5.2.2 Spring DEPM surveys

This year the only DEPM survey that was carried out was the BIOMAN survey. This survey has been conducted by AZTI every year since 1987 in May, targeting anchovy and sardine in the Bay of Biscay (ICES divisions 8abcd). The other DEPM surveys are conducted every three years.

#### 5.2.2.1 Oceanographic conditions

In 2018 the spring DEPM surveys BIOMAN for sardine and anchovy was conducted in May as usually, from the 7$^{th}$ to the 28$^{th}$. The sea surface temperatures ranged from 12ºC to 17.5ºC with a mean of 15.2ºC, higher than last year mean (14.8ºC). Lower values were observed in the Gironde estuary and the Adour area of influence as usual, and a warmer area was observed in the North of the French platform (**Fig. 5.2.2.1.1**). Sea surface salinity ranged from 31.52 to 35.96 with a mean of 34.41 lower than last year mean (35.12). This year the high discharge of the rivers is observed on the low salinities in the area of influence of the rivers Garonne in the North and Adour in the South (**Fig. 5.2.2.1.1**).

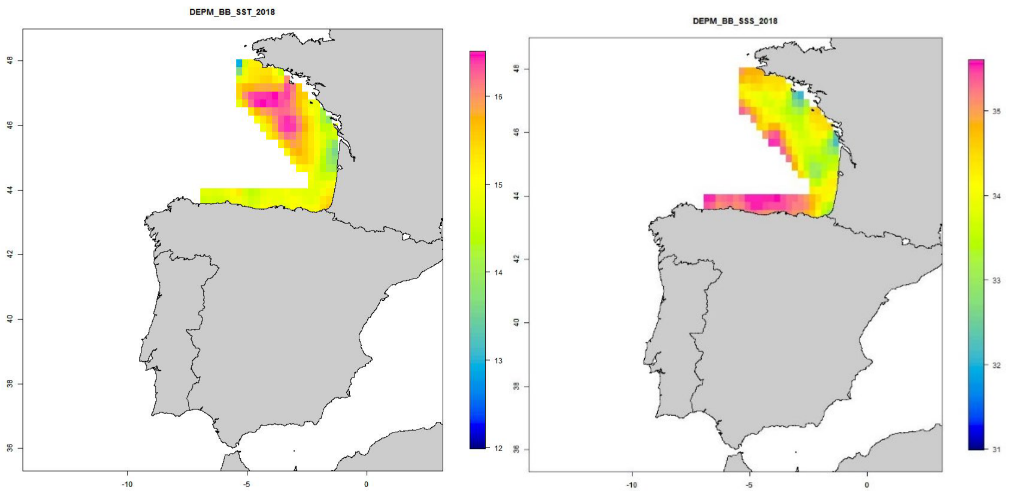



**Figure 5.2.2.1.1 Sea surface temperature (left) and salinity (right) during DEPM survey BIOMAN2018 (May).**

### 5.2.2.2 Anchovy and sardine egg distributions from CUFES and PairoVET observations

Anchovy egg distributions patterns derived from PairoVET and CUFES sampling carried out during 2018 DEPM survey BIOMAN (**Fig. 5.2.2.2.1**) showed eggs all over the French platform, until 200m depth, up to 47º30’N were the limit of the spawning was found. This year 12% of the anchovy eggs were found in the Cantabrian Coast. The survey arrived until 6º12’W, the most west longitude ever reached in the historical series. There were some anchovy eggs at the limit of the 8abd at 48ºN. The same pattern distribution is observed with both samplers PairoVET and CUFES.

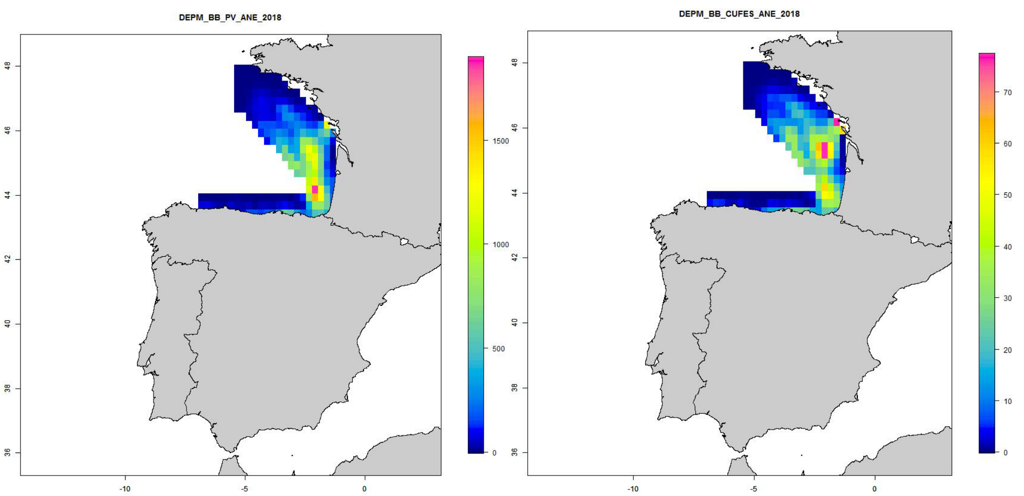



**Figure 5.2.2.2.1 Anchovy egg distributions from PairoVET (left; eggs/m2) and CUFES (right; eggs/m3) observations collected during BIOMAN survey.**

Sardine egg distributions patterns derived from CUFES and PairoVET observations during the 2018 DEPM surveys (**Fig.5.2.2.2.2**) show low abundances all along the Cantabric coast surveyed. There were abundances encountered in all the French platform, high abundances were encountered in the South, between coast and 100m depth isoline and in the North in the middle of the platform until 47.30ºN, where the north spawning limit was found. The same pattern distribution is observed with both samplers Pairo-VET and CUFES

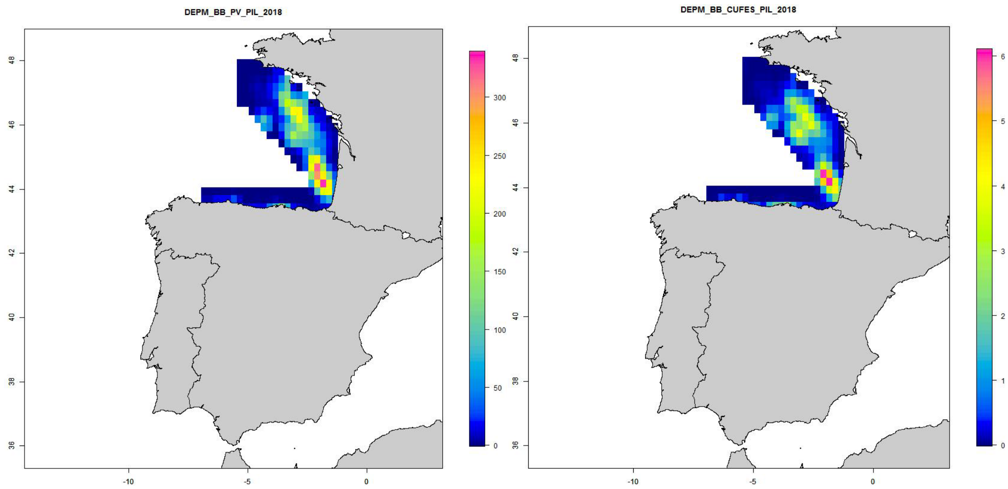



**Figure 5.2.2.2.2 Sardine egg distributions from PairoVET (left; eggs/m2) and CUFES (right; eggs/m3) observations collected during DEPM BIOMAN surveys.**

### 5.2.3 Gulf of Cadiz summer survey

The ECOCADIZ 2018-07 survey was carried out between 31st July and 13rd August 2018 onboard the Spanish R/V Miguel Oliver covering a survey area comprising the Spanish and Portuguese waters of the Gulf of Cadiz, from Strait of Gibraltar to Cape San Vicente, between the 20 m and 200 m isobaths. The main objectives of this survey were the acoustic assessment (by echo - integration) and mapping of neritic fish resources and of the oceanographic and biological conditions off the Gulf of Cadiz continental shelf (**Fig. 5.2.3.1**).

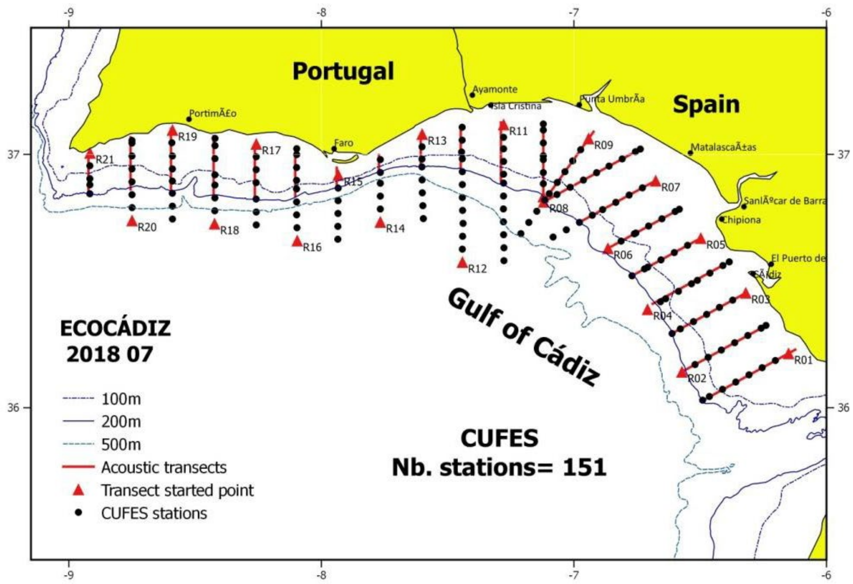



**Figure 5.2.3.2.1. ECOCADIZ 2018-07 survey. Location of the CUFES stations and acoustic transects.**

#### 5.2.3.1 Oceanographic conditions

The observed patterns of Sea Surface Temperature and Salinity (SST and SSS, respectively) during the survey have been similar to those ones recorded in previous years, with a mean SST and SSS of 20.4 $^{0}$C and 36.0 PSU, respectively, for the whole surveyed area. Colder waters, as usual, were recorded in the area West of Cape Santa Maria, there were regional differences in the range of salinities observed lower SSS towards cape S.Vicente and higher in Cadiz Bay between both areas (East and West of Cape Santa Maria) (**Fig. 5.2.3.1.1**).

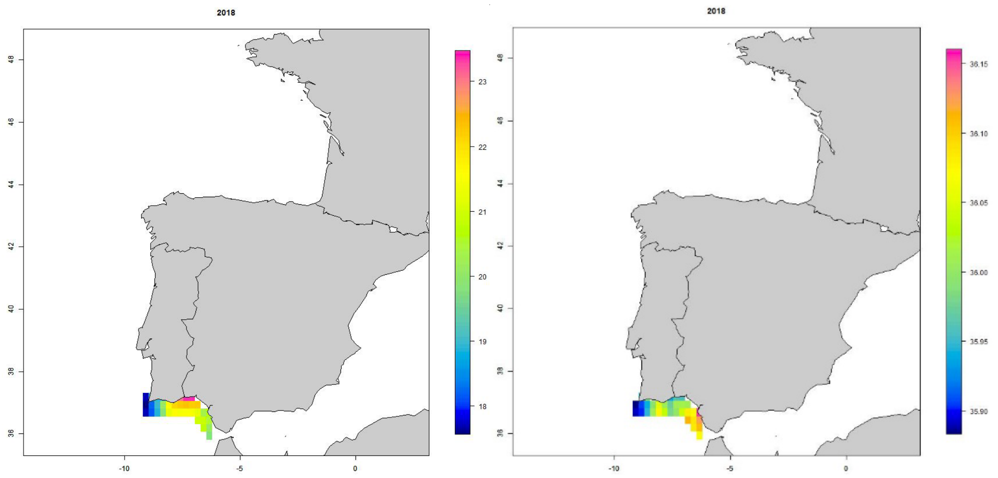



**Figure 5.2.3.1.1. SST (left) and SSS (right) recorded during the ECOCADIZ 2018-07 survey.**

#### 5.2.3.2 Anchovy egg distribution from CUFES Observations

The Gulf of Cadiz anchovy egg distribution from CUFES sampling is shown in **Figure 5.2.3.2.2**. Anchovy egg distribution and densities in summer 2018 are quite coincident with that of adults. The estimated total egg density is at the same magnitude than the observed in the most recent years, but such estimates are lower than the historical average.

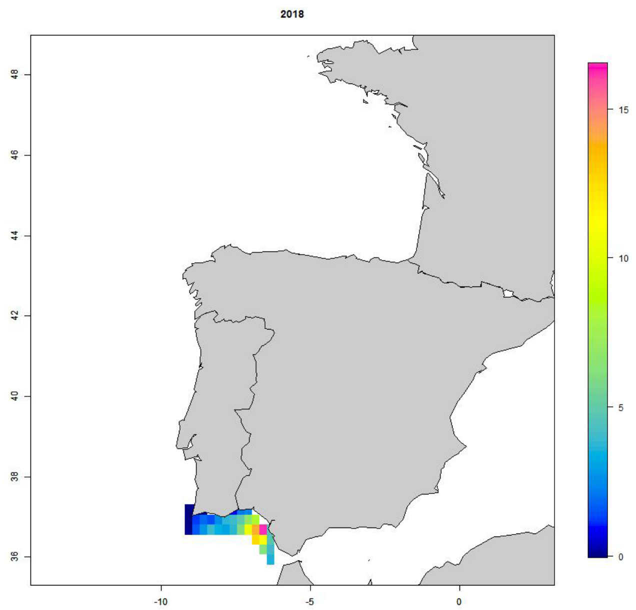



**Figure 5.2.3.2.2: ECOCADIZ 2018-07 survey. Spatial distribution of anchovy eggs density (eggs/m3) by CUFES.**

#### 5.2.3.3 Trawl haul catch composition

A total of 25 fishing operations for echo-trace ground-truthing (all of them valid ones according to a correct gear performance and resulting catches), were carried out during the survey (**Fig. 5.2.3.3.1**). The sampled depth range in the valid hauls oscillated between 41-185 m. A detailed description on the conduction of these hauls is given in Ramos *et al.* (2018 WD in Annex 3).

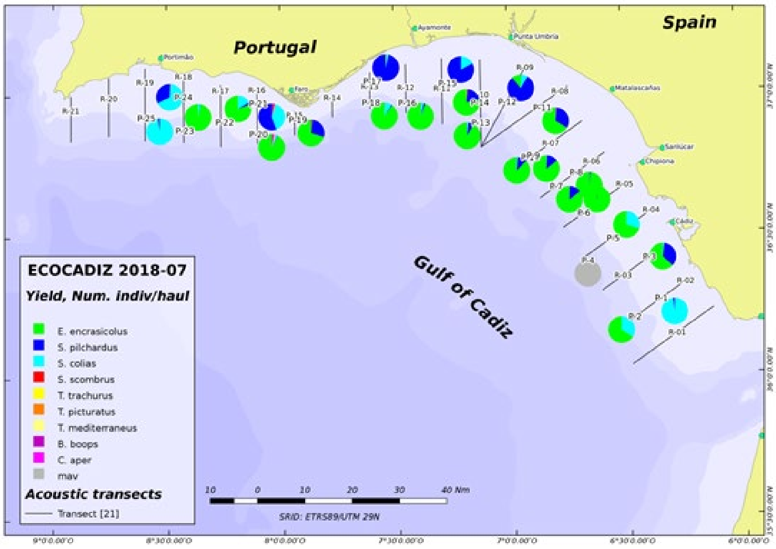



**Figure 5.2.3.2.2: ECOCADIZ 2018-07 survey. Spatial distribution of anchovy eggs density (eggs/m3) by CUFES.**

During the survey were captured 1 Chondrichthyan, 29 Osteichthyes, 5 Cephalopod and 3 Crustacean species. The percentage of occurrence of the more frequent species in the hauls is shown in **wd Ramos *et al.* in annex 3**

The species composition, in terms of percentages in number, in each valid fish station is shown in **Figure 5.2.3.2.1**. A first impression of the distribution pattern of the main species may be derived from the above figure. Thus, anchovy showed a relatively wide distribution over the surveyed area, although the highest yields were recorded in the Spanish waters. Sardine was also widely distributed in the surveyed area. Chub mackerel, horse mackerel, blue jack mackerel and bogue, although they occurred in a great part of the study area, only showed relatively high yields in the Portuguese waters. Mediterranean horse mackerel was restricted to the easternmost Spanish waters.

#### 5.2.3.4 Adult sardine and anchovy acoustic density (NASC) distribution

**Sardine** recorded a very high acoustic echo-integration in summer 2018 (ca. 49% of the total acoustic energy allocated to fish) as a consequence of the occurrence of very dense mid-water schools in the coastal fringe (20-50 m depth) comprised between Tavira (eastern Algarve) and the surroundings of the Guadalquivir river mouth (central Spanish waters). The distribution pattern of acoustic densities is quite similar to the one provided by the PELAGO survey in spring although the occurrence of sardine in the surveyed area was more continuous in summer (**Fig. 5.2.3.4.2**).

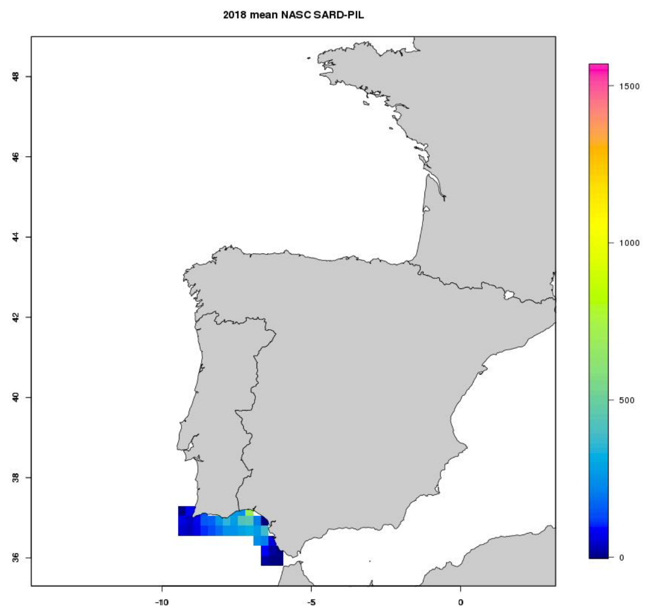



**Figure 5.2.3.4.2: Sardine (*Sardina pilchardus*) acoustic density (NASC, m2 nm-2) map derived from the ECOCADIZ 2018-07 Gulf of Cadiz summer acoustic survey, 0.25⁰ map cell.**

**Anchovy** (18% of the total acoustic energy attributed to fish) was widely distributed over the surveyed area, although showing the highest densities in the Spanish shelf waters between El Rompido and Bay of Cadiz, and in a secondary nucleus located over the Portuguese shelf, between Alfanzina and Cape of Santa Maria (**Fig. 5.2.3.4.3**). This distribution pattern differed from the one exhibited during the PELAGO spring survey, when anchovy was restricted to a zone comprised between Vila Real de Sto. Antonio (easternmost Portuguese waters) and the Bay of Cadiz.

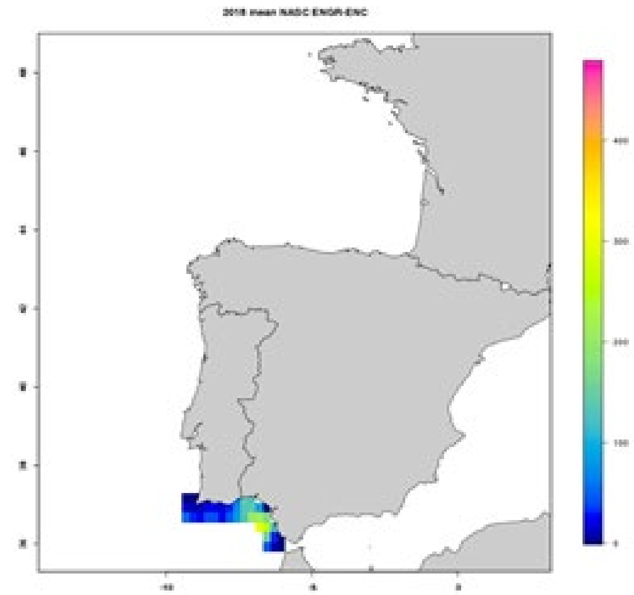


**Figure 5.2.3.4.3: Anchovy (*Engraulis encrasicolus*) acoustic density (NASC, m2 nm-2) map derived from the ECOCADIZ 2018-07 Gulf of Cadiz summer acoustic survey, 0.25⁰ map cell.**

#### 5.2.3.5 Other adult small pelagic fish species acoustic density distributions

Atlantic mackerel (*Scomber scombrus*) showed very low acoustic records during the 2018 survey, which were mainly observed all over the shelf located in the central part of the Gulf of Cadiz (Fig. 5.2.3.5.1 a).

Contrarily, the acoustic energy allocated to its close relative, Chub mackerel (*Scomber colias*), accounted for 21.5% of the total acoustic energy attributed to fish in the survey. The population was mainly concentrated in the western-most waters of the Gulf, between Cape San Vicente and Cape Santa Maria, with a secondary nucleus of fish density in the easternmost waters, from the Bay of Cadiz to the Strait of Gibraltar (Fig. 5.2.3.5.1 b).

Horse mackerel (*Trachurus trachurus*) showed very low acoustic densities in the surveyed area, with the species being almost absent in the easternmost shelf and showing relatively higher densities in the shelf area comprised between Cape San Vicente and Cape Santa Maria (Figure 5.2.3.5.1 c).

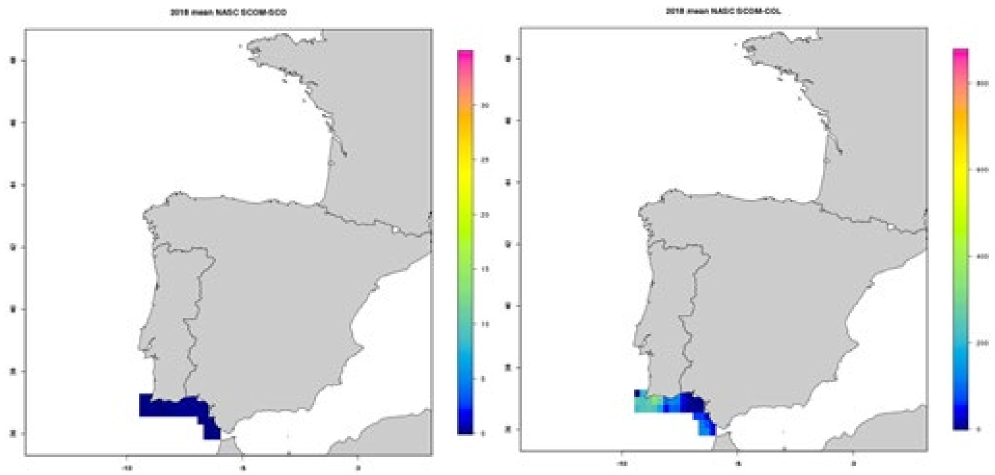
Mediterranean horse mackerel (*T. mediterraneus*) was restricted, as usual, to the Spanish waters, with the highest densities being recorded in the inner shelf waters of the central part of the Gulf (Figure 5.2.3.5.1 d).

The distribution pattern of the very low acoustic densities attributed to Blue jack mackerel (*T. picturatus*) closely resembled to the described one for horse mackerel (Figure 5.2.3.5.1 e).

Bogue (*Boops boops*) was distributed practically all over the shelf of the surveyed area, although showed its highest densities in the inner shelf of both the central and westernmost waters of the Gulf (Figure 5.2.3.5 f).

Boarfish (*Capros aper*) showed an incidental occurrence restricted to the outer shelf waters jus to the west of Cape of Santa Maria (Figure 5.2.3.5.1 g).

The constant occurrence of Pearlside (*Maurolicus muelleri*) in somewhat shallower waters than usual in the 2018 survey has resulted in its acoustic detection in the surveyed area (9% of the total acoustic energy), just in the transition between outer shelf and upper slope waters. Higher densities were recorded in the Spanish outer shelf (Figure 5.2.3.5.1 h).



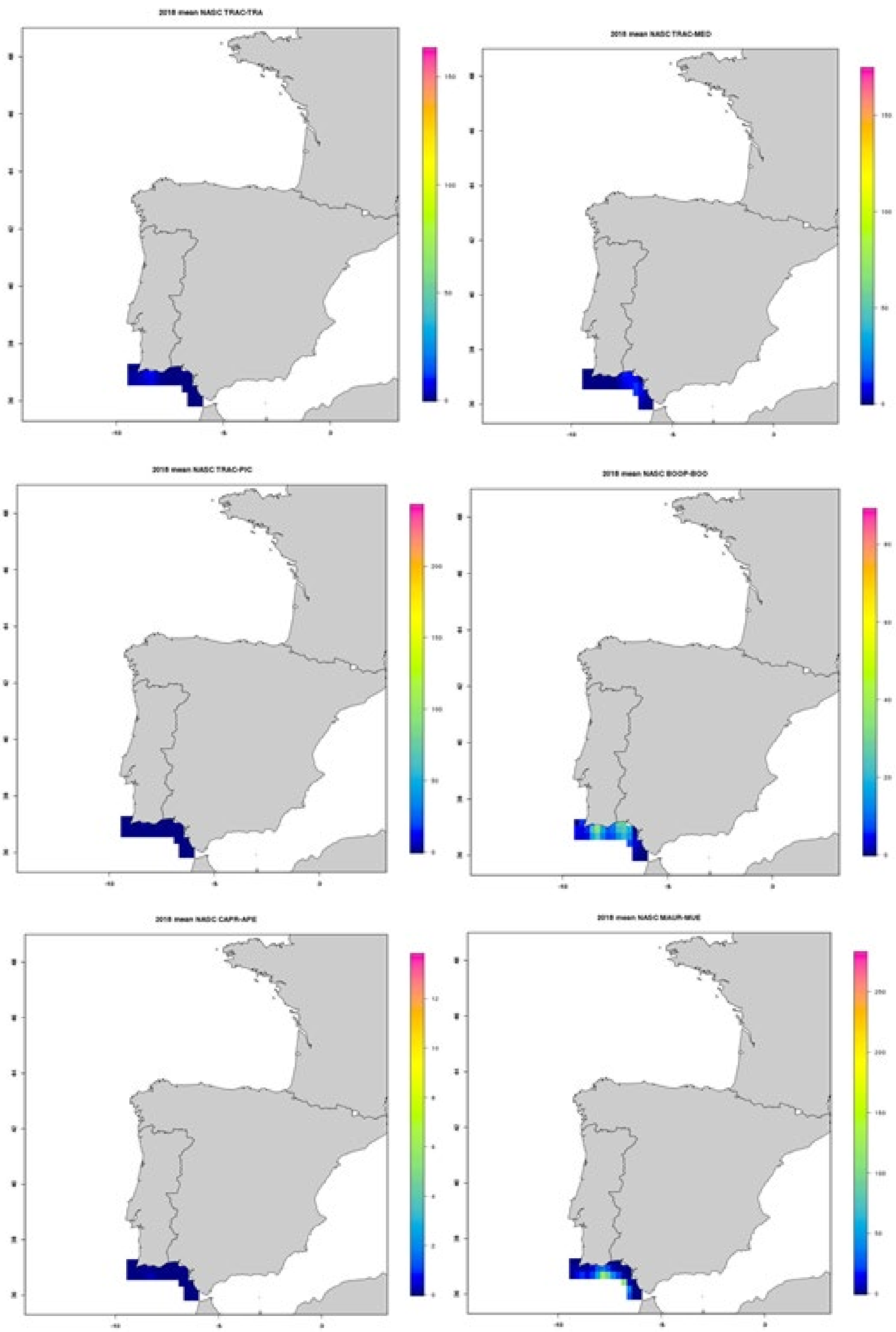



**Figure 5.2.3.5.1: Atlantic mackerel (*Scomber scombrus*)(a), Chub mackerel (*Scomber colias*)(b), Horse mackerel (*Trachurus trachurus*) (c), Mediterranean horse mackerel (*T. mediterraneus*)(d), Blue jack mackerel (*Trachurus picturatus*)(e), Bogue (*Boops boops*)(f), Boarfish (*Capros aper*) (g), Pearlside (*Maurolicus muelleri*) acoustic density (NASC, m2 nm-2) maps derived from the ECOCADIZ 2018-07 Gulf of Cadiz summer acoustic survey, 0.25$^{0}$ map cell.**

### 5.2.4 Autumn acoustic surveys

#### 5.2.4.1 Oceanographic conditions

The autumn oceanographic conditions observed during the JUVENA and PELTIC surveys showed distinct regional patterns. Salinity values were generally high, particularly in the Celtic Sea (~48-52°N) which was slightly saltier as a whole than the Bay of Biscay (~44-48°N) and also more saline than previous years. This was likely due to the unusually warm and dry summer experienced in the northern part of the study area which would have meant that fresh water outflow from rivers was lower than usual. The usual influence of the freshwater input from rivers was observed in the Bristol channel. The Bay of Biscay was in general less saline particularly in the offshore waters of the centre of the Bay of Biscay in the Cap Ferret area. The exceptionally high salinities at the North of the French shelf and around the Gironde plume are based on individual casts and will be revised for next year (**Fig.5.2.4.1.1**).

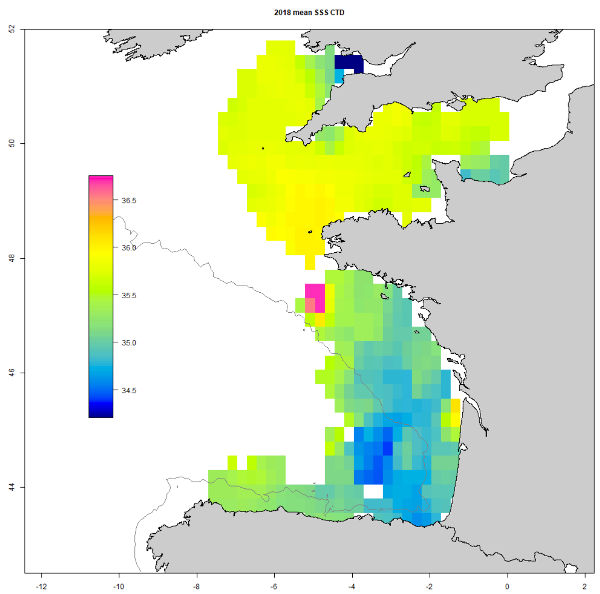



**Figure 5.2.4.1.1: Mean surface salinity (psu) maps derived from the JUVENA and PETIC surveys carried out in 2018 using a 0.25° map cell.**

As expected, the regional sea surface temperatures were higher in the southern area, the Bay of Biscay, compared to the cooler waters of the Celtic sea (**Fig. 5.2.4.1.2**), although to some extent this was due to the temporal offset between JUVENA (September) and PELTIC surveys (October-November). The warmest waters were found in the central Cantabrian coast, whereas the coldest surface waters, which also were the most saline, were found off Brittany coast, part of the Ushant front that prevails in the opening of the English Channel. Conversely, the warmest waters off the Cantabrian coast were associated with low salinity.

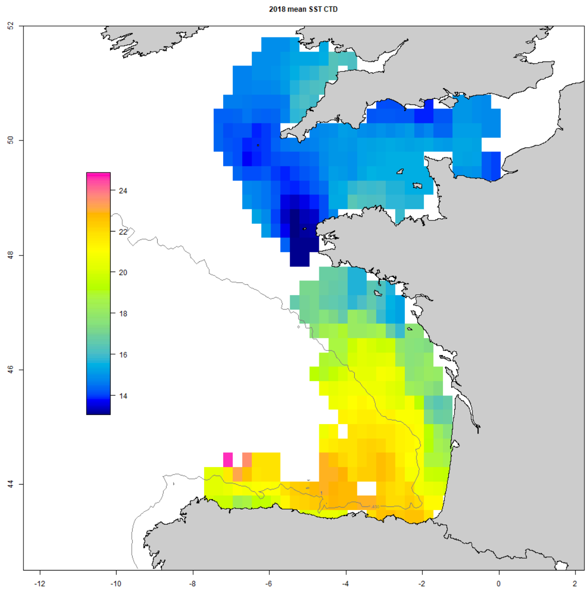



**Figure 5.2.4.1.2: Mean autumn sea surface temperatures (SST, °C) derived from the JUVENA and PELTIC surveys carried out in 2018 using a 0.25° map cell.**

### 5.2.4.2 Trawl haul catch composition

Although fishing hauls are normally conducted to provide ground-truth to the echotraces recorded by the echosounders and to estimate an age/length spatial distribution by species along the surveyed area, thus done in an opportunistic way, they will reflect the abundance of the main pelagic fish species related to the echotraces. **Figure 5.2.4.2.1** shows the percentage (in weight) of the fishing stations done during the autumn acoustic surveys, JUVENA in the Bay of Biscay and PELTIC in the English Channel. Anchovy was the most important species in the JUVENA catches. Catches are more mixed in the Channel. The sprat is dominant in the Bristol channel and sardine seems to be well present in the western Channel, sometimes mixed with anchovy.

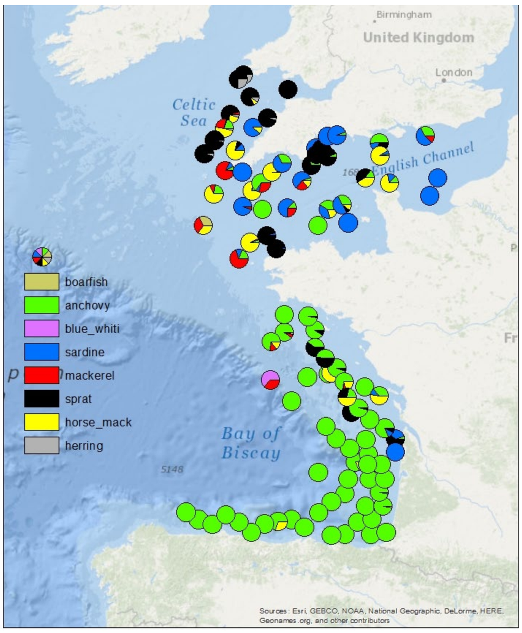



**Figure 5.2.4.2.1 percentage (in weight) of fishing stations during autumn acoustic surveys, JUVENA (Bay of Biscay) and PELTIC (English Channel).**

### 5.2.4.3 Adult sardine and anchovy acoustic density (NASC) distribution

The combined acoustic data from JUVENA and PELTIC provided a global overview of autumn distribution of sardine in western European waters (**Fig. 5.2.4.3.1**). For the second year running, survey coverage was continuous from the Cantabrian Coast of northern Iberia to the Celtic Sea.

Sardine distribution patterns in 2018 were comparable to those in the previous years (2015 - 2017): it was largely absent from the southernmost areas but was found in the coastal waters of the central part of the French shelf of the Bay of Biscay and was widespread in the English Channel, with low densities of sardine also found north of the Cornish Peninsula.

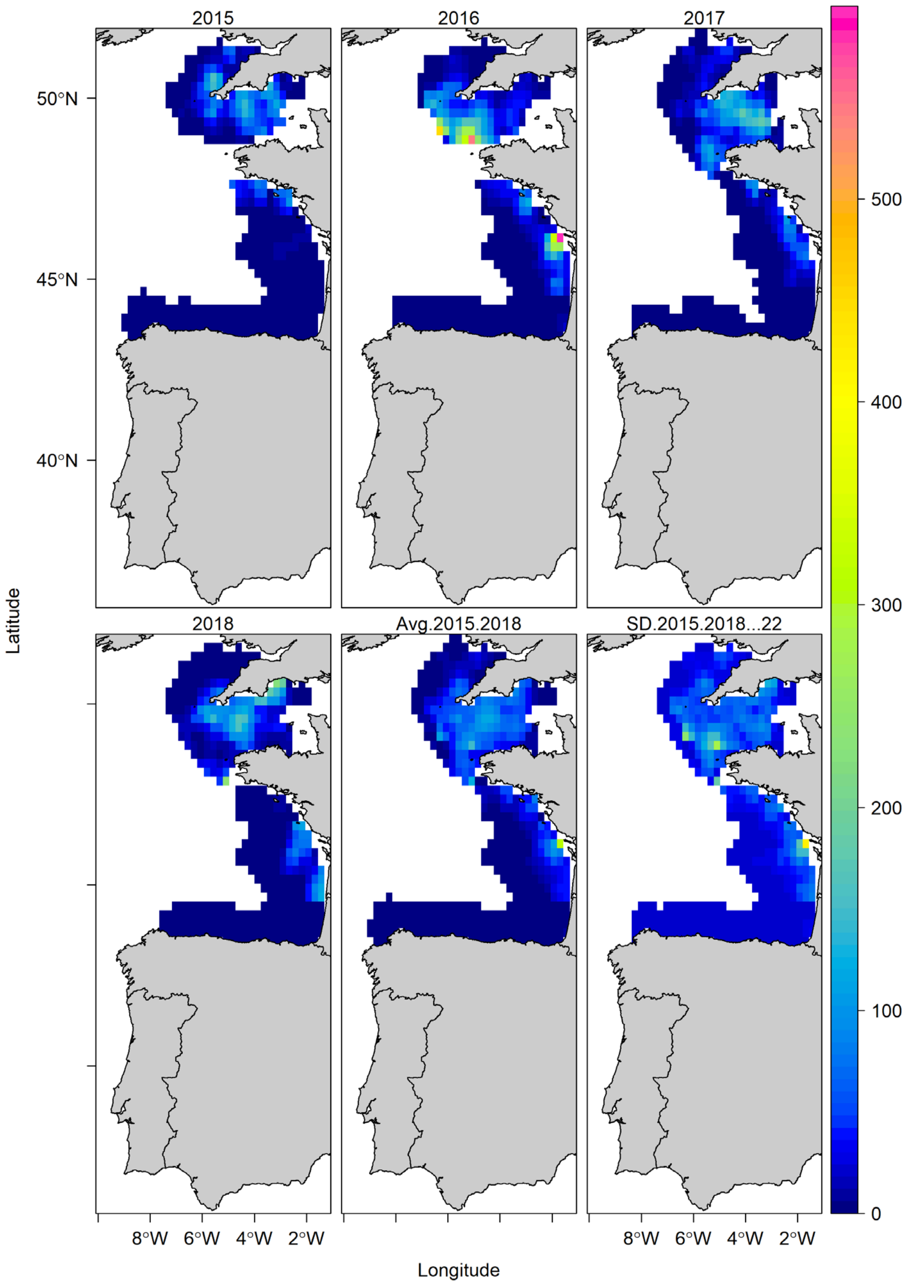



**Figure 5.2.4.3.1. Mean backscattering energy (NASC, m2 mn-2) per 0.25°x 0.25° square allocated to sardine for the combined JUVENA and PELTIC autumn acoustic surveys. From left to right: 2015, 2016, 2017 (top); 2018, average backscatter for the four years, and the standard deviation (bottom).**

The 2018 adult anchovy distribution in the Bay of Biscay showed low anchovy backscatter values along the Spanish coast and highest densities in the northernmost part of the shelf waters at French sector. Anchovy biomass in the English Channel was significantly higher and more widespread than in 2017. **Fig. 5.2.4.3.2.**

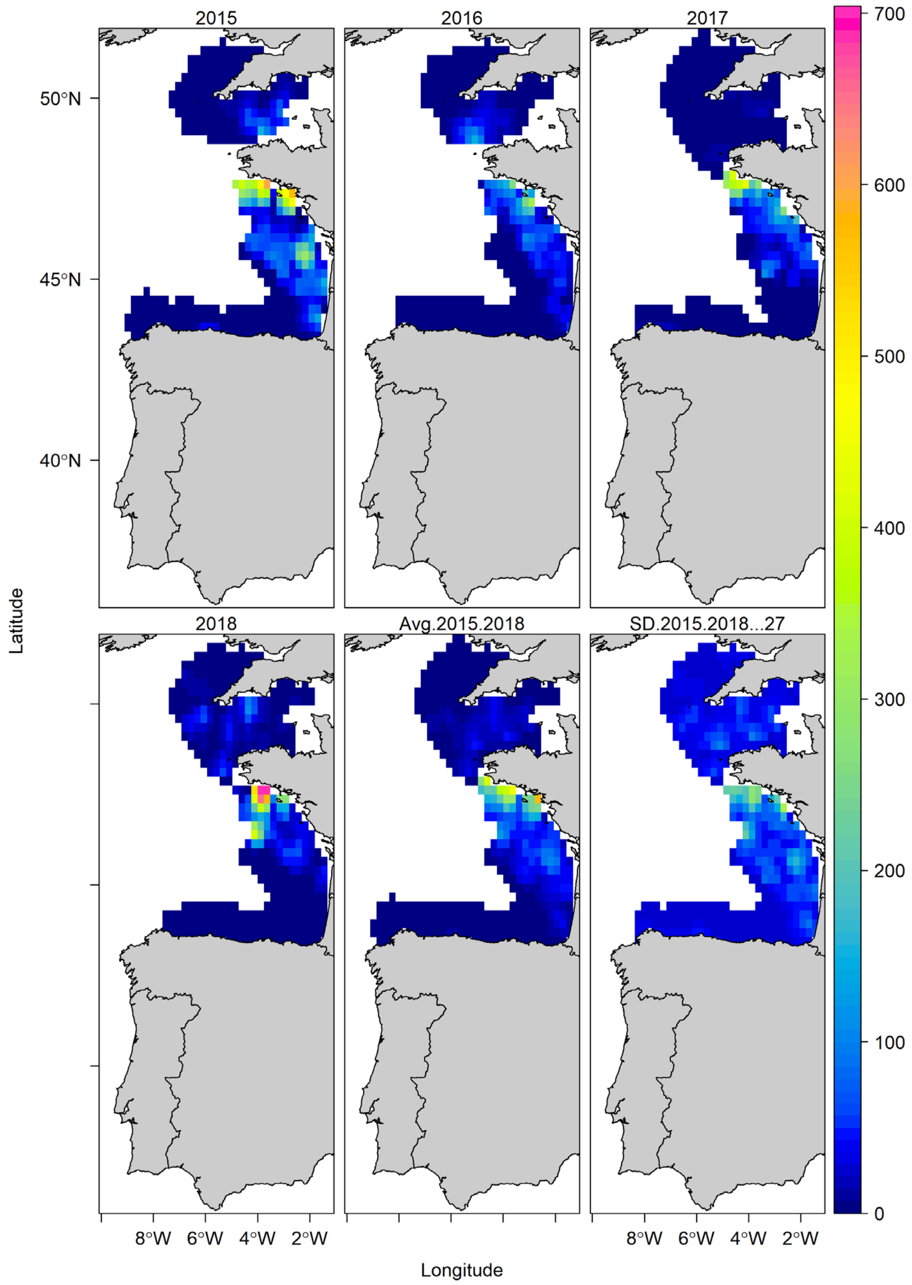



**Figure 5.2.4.3.2. Mean backscattering energy (NASC, m2 mn-2) per 0.25°x 0.25° square allocated to anchovy for the combined JUVENA and PELTIC autumn acoustic surveys. From left to right: 2015, 2016, 2017(top); 2018, average backscatter for the four years, and the standard deviation (bottom).**

The 2018 juvenile anchovy distribution showed the highest concentrations at the South-eastern part of the Bay of Biscay, distributing also along the Cantabrian Sea and French continental shelf. In contrast to the Bay of Biscay, juvenile anchovy in the English Channel tend not to be segregated from adults and because they are generally found mixed in small numbers with adults, juvenile anchovy backscatter is not mapped separately during PELTIC. **Fig. 5.2.4.3.3**.

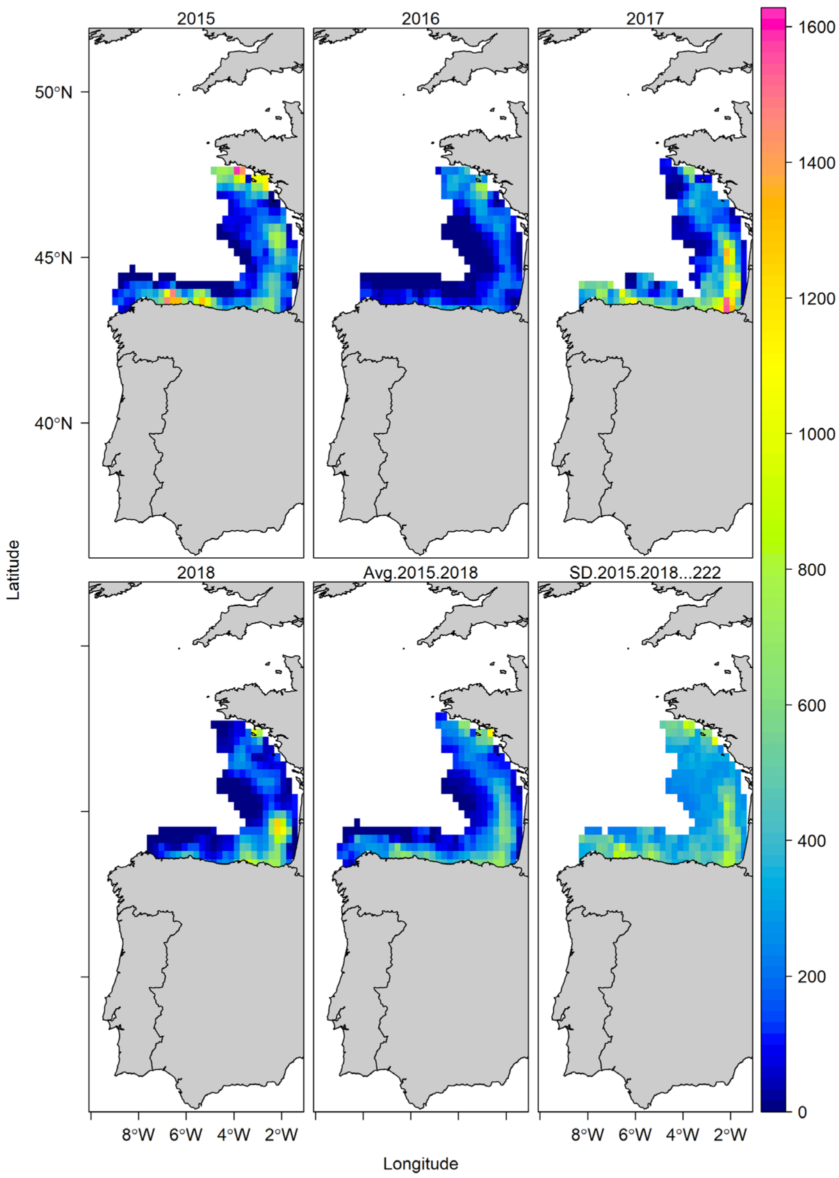



**Figure 5.2.4.3.3. Mean backscattering energy (NASC, m2 mn-2) per 0.25°x 0.25° square allocated to juvenile anchovy for the JUVENA autumn acoustic survey. From left to right: 2015, 2016, 2017(top); 2018, average backscatter for the four years, and the standard deviation (bottom).**

### 5.2.5 Summary of the gridded data analysis session

Multiple Factorial Analysis (MFA) (~ PCA on grouped data) was performed on the gridded maps produced by WGACEGG, to analyse the anchovy and sardine spatio-temporal distribution and habitats in the European Atlantic Area (EAA).

Data matrices were formed with gridded maps cells as rows, and annual parameter values as columns, grouped by years and submitted to MFA. MFAs were performed on gridded maps from spring acoustic surveys describing: i) environment (SST and SSS), and ii) fish (anchovy and sardine) acoustic densities (NASC), over the 2004-2008, 2010-2011, 2013-2017 time period. Environment and fish variables were summarised by their two first MFA loadings (MFA1&2). Relationships between fish and environment MFA1&2 were explored to assess the potential environmental drivers of fish distributions.

Environment MFA1 (43% var. expl.) was positively correlated with SSS, and frequently with SST. Higher SSS and sometimes SST were observed in southern areas, offshore Biscay and Cantabrian Sea (**Fig. 5.2.5.1**). Environment MFA2 (29% var. expl.) was consistently positively correlated with SST. Higher SST values were observed in coastal Biscay and southern areas (Fig. 1). No significant warming trend was found in SST at this time of the year.

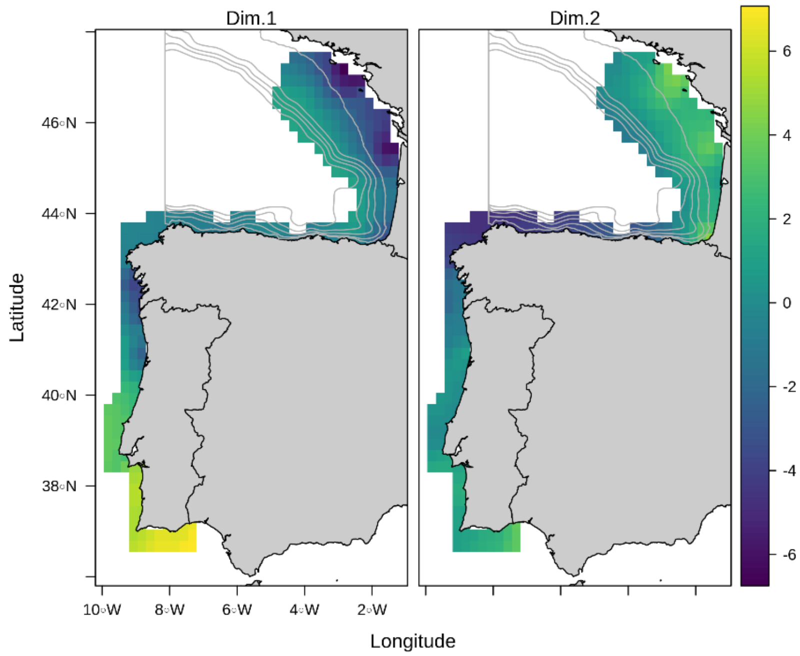



**Figure 5.2.5.1 Maps of environment MFA1 (left) and MFA2 (right) loadings.**

Anchovy and sardine NASC were consistently correlated with fish MFA1 (48% var. expl.). Persistent core distribution areas of anchovy and sardine were SW Iberian and Southern Biscay areas (MFA1>0 in **Fig. 5.2.5.2**). Sardine NASC was correlated with MFA2 (15% var. expl.). Higher sardine densities were observed in Western Iberian and North coastal Biscay areas until 2007 (MFA2>0 in **Fig. 5.2.5.2**).

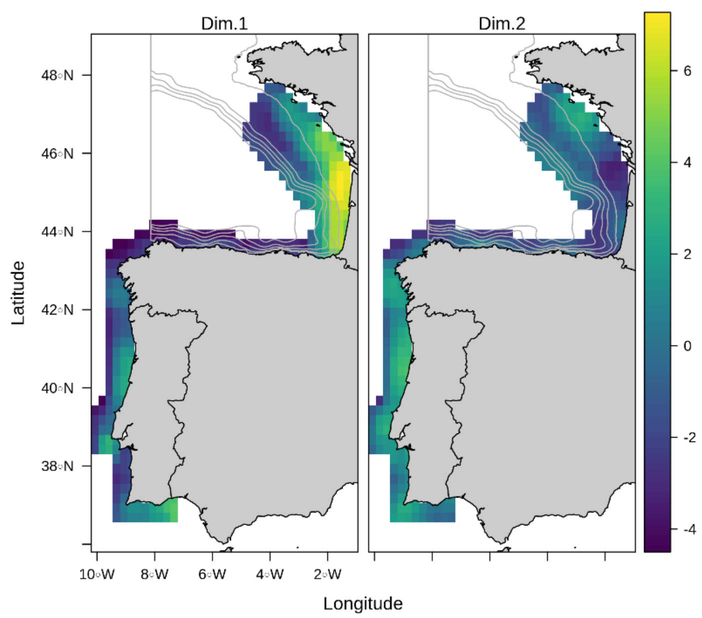



**Figure 5.2.5.2 Maps of fish MFA1 (left) and MFA2 (right) loadings.**

After 2007, MFA2 loadings averaged over the whole area, i.e. a proxy for sardine NASC, has dropped (**Fig. 5.2.5.3**).

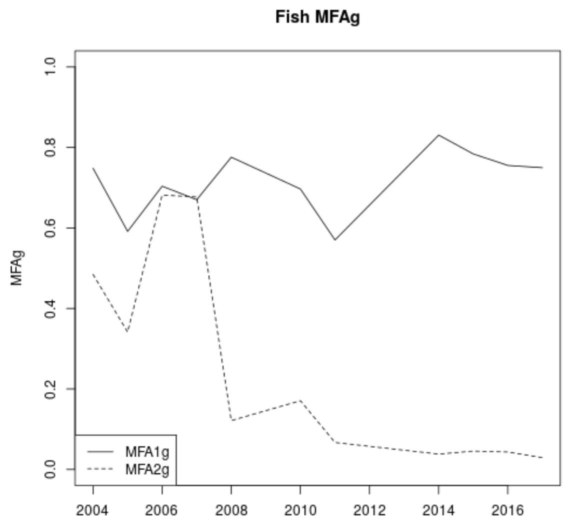



**Figure 5.2.5.3 Time series of fish MFA1&2 loadings averaged over the whole area**

Environment MFA1&2 explained 3% and 53% of fish MAF1, respectively (linear model). Anchovy and sardine habitats were then characterised by higher SST in southern areas and coastal Biscay. Fish MFA2 was not explained by environment MFA1&2 (linear model). Fish landings in area 9 however explained 67% of fish MFA2 in West Iberian area (Generalised linear model, Gamma family, log-link).

In conclusion, this study is the first synoptic assessment of anchovy and sardine habitat extension and occupation variability at the European Atlantic Area scale. MFA1&2 derived from fish and environment datasets proved to be useful proxies to summarise spatial and temporal variability of ecosystem components. Anchovy and sardine large scale distribution was correlated with relatively higher SST in southern Iberian and coastal Biscay areas. Sardine higher densities in western Iberian and offshore northern Biscay areas were not explained by available environmental indices. A significant statistical correlation was found between landings and decreasing sardine densities in Western Iberian area. Further studies should be conducted to assess if fishing might have played a role in the sardine stock decline in this area.

Anchovy and sardine egg densities from CUFES were analysed together with NASC values and displayed similar spatial and temporal patterns in the fish distribution. Relationships with environment and fishing were however less clear when analysing egg and acoustic data together. This might indicate that local spatial variations in CUFES egg abundance and NASC distributions are not parallel, for instance due to not proportional differences in daily fecundity or backscattering properties of big and small fishes which are spatially segregated, or for instance in CUFES sampling properties in space. As a consequence, the relationship between fish and environment MFA might be blurred. Further studies should be conducted to assess the impact on fish distribution maps of local spatial variability in the scaling factors used to translate acoustic and CUFES egg densities into fish biomass.

#### WGACEGG gridded maps database consolidation, hosting and valorisation

WGACEGG members agreed to consolidate time series of survey indices and gridded maps and to host them in an instance of the EchoBase relational database hosted at Ifremer for utilization within the WG work.

It was also agreed to: i) publish datasets extracted from the database in the ICES dataset archive when this service is available, ii) link the WGACEGG database to the ICES map service, to allow for the display of WGACEGG gridded maps together with other data stored in the ICES acoustic and trawl database.

All data providers but IPMA agreed to adopt the ICES metadata convention for processed acoustic data and the ICES data portal for acoustic trawl surveys data storage. IPMA representatives were not entitled to agree on these terms and had to refer internally first.

## 5.3 Methodological developments for acoustic and DEPM biomass assessment

### 5.3.1 Methodological developments for acoustic biomass assessment

**Preliminary analysis of the effect of the ping rate on the average NASC.** Guillermo Boyra, Andrés Uriarte and Udane Martinez

The recent increase in interest in mesopelagic species of acoustic surveys traditionally targeting epipelagic species has caused some surveys to increase their detection range. To test the impact of this on the acoustic estimates, the effect of a successive ping reduction on the average of NASC values has been studied. The results (**Annex 5.3.1**) indicated a decrease in the descriptive random error (i. e., standard deviation) with the increasing ping rate, but an increase of the inferential random error (i.e., standard error), due to reduction of the sampling effort in the transect. A slight decrease of the averaged NASC with the ping rate increase was also reported, probably due to the extremely skewed distribution of NASC values.

**Ex-situ TS measurements of European anchovy in a harbour cage.** Bea Sobradillo and Guillermo Boyra

This study measures dorsal aspect target strength (TS; dB re 1 $m^2$) and models TS-length (L; cm) relationships as TS = 20log(L) + b20 for European anchovy in a harbour cage at three frequently used acoustic frequencies, including the one used for assessment. A backscattering model for physostome fish where the swim bladder was simulated as two chambered prolate spheroids was used to help interpret the results. The obtained TS values were -45.5, -47.5 and -49.5 dB at 38, 120 and 200 kHz respectively, which, for the 10.5 ± 1 cm long anchovies studied, yielded b20 values of -66, -68 and -70 dB. This is part of a series of efforts planned to obtain a comprehensive TS versus length relationship to update the acoustic assessment methodology of European anchovy in the Bay of Biscay. (More details in **Annex 5.3.1)**

**FSP 2018-2019: Self sampling programme: Acoustic sprat survey in Lyme Bay**. Sílvia Rodríguez Climent

A Fisheries Science Partnership (FSP) survey was carried in parallel to the PELTIC18 survey to evaluate the sprat (*Sprattus sprattus*) population using fisheries acoustics and pelagic trawling in Lyme Bay (UK). Specific objectives were to identify the amount of sprat biomass that resides in the shallow inshore waters that could not be covered by the research vessel, the effect of patchiness on the detectability of sprat based on the existing and to compare the biomass estimated by the two surveys. At the time of writing the report, the analysis was not completed but preliminary results suggested that despite two weeks of difference in the timing of the two surveys, the location of sprat was not significantly different within the bay (**Annex 5.3.1**).

**Multibeam echosounder for fish school characterization.** Nans Burgarella, Laurent Berger, Mathieu Doray and Pierre Petitgas

In stock evaluation and shoaling behaviour study, multibeam echo-sounders can bring several benefits when compared to classical single beam echo-sounders. Access to three-dimensional data gives additional shape and structural information on shoals, therefore allowing for better identifications of the species forming the school. Using a simulation approach, we searched for areas of lower acoustic density on shoals created with a uniform density. We found that, when individuals in a shoal are not aligned with the boat progression axis, differences in insonification angle can lead to the appearance, on the echogram, of areas appearing as having a lower density that do not correspond to actual changes in the density or orientation pattern of individuals in the shoal. This effect only appeared on the axis athwart to the boat progression as it is the axis over which beam angle varies. In the situation of a stock evaluation conducted with a multi-beam echo-sounder, underestimation of densities on the external beams due to incidence angle variation could lead, over the course of a campaign, to an underestimation of stock size. (**See Annex 5.3.1**)

**Characterization of Bay of Biscay sound scattering layers using broadband acoustics, nets and video.** Arthur Blanluet, Mathieu Doray, Laurent Berger, Jean-Baptiste Romagnan, Naig Le Bouffant, Sigrid Lehuta and Pierre Petitgas

Broadband acoustics were used to test the hypothesis on the gas bearing-based composition of the sound scattering layers observed during PELGAS spring survey. The forward approach was used to link the acoustic scattering to the biological sampling. This consisted on modelling the theoretical backscattering of the sampled organisms and compare it to the measured backscatter. Also, a clustering of the backscattering spectrum was performed to further investigate the composition and homogeneity at the different layers. Sampling was performed in two zones: the continental shelf and the slope, and three different layers were studied: daytime surface, daytime deep and night time surface layers. The reported results showed an important contrast in composition between the two zones: pteropods and big siphonophores dominating the continental shelf zone, while mesopelagic fish, copepods and euphausiids dominated the slope zone. The results reported on the clustering analysis showed that the SSL presented generally more complex internal structure of spectra than the echogram´s visual homogeneity (**Annex 5.3.1**).

**Echosonde project and Phoenix project (including update on EK80).** Mathieu Doray

Two large scale offshore windfarms are to be built near the French Pays de la Loire region coast. The impact of Marine Renewable Energy production units' impact on pelagic organisms is poorly known. The Ec(h)oSonde project aims at developing a prototype of integrated acoustic observatory to monitor the impact of renewable marine energy (RME) on coastal pelagic ecosystems. The Ec(h)oSonde project will lead to the development of an integrated acoustic observatory including an innovative broadband echosounder, Simrad EK80 operating in the 70, 120, 200 and 333kHz band. The Ec(h)oSonde will be deployed in March-April 2019. Several sea surveys have been conducted in the Ec(h)oSonde area onboard small (20 m R/V Thalia) and large (70m R/V Thalassa, PHOENIX2018 survey) since June 2017. The objectives were to: i) test in-situ the Ec(h)oSonde echosounder, ii) collect biological data to ground truth Ec(h)oSonde recordings and to characterise the local pelagic environment. **See Annex 5.3.1**.

**ICES Acoustic Trawl Data Portal.** Hjalte Partner

The ICES Acoustic Trawl Data Portal at https://acoustic.ices.dk is in production and serves a number of ICES coordinated surveys.

The database behind stores processed acoustic and biotic data, validated and quality controlled during the submissions process and the output aims on serving abundance indices estimation software packages like StoX and EchoR. (**More information in Annex 5.3.1**).

### 5.3.2 Methodological developments for DEPM biomass assessment

During the DEPM subgroup some presentations took place related to the following subjects:

**A joint effort across marine laboratories for improving spawning frequency estimations in fishes.** Ganias K. *et al.* Aristotle' University of Thessaloniki (AUTH). Greece.

During the ICES-WGALES meeting held in Thessaloniki in October 2016 an initiative was taken by the participants of the Plenary Session on Adults for the development of a new method (or methods) for estimating spawning frequency. This new method should be applicable to any kind of spawners/species and is anticipated to improve accuracy and reduce cost and effort in applications of Egg Production Methods. This ambition led to a collaborative mission headed by Aristotle' University of Thessaloniki (AUTH) and the Institute of Marine Re-search at Bergen (IMR) with the participation of AZTI-Tecnalia, Wageningen Marine Research, IEO, IPMA and DTU-Aqua. The material for the method development was based on ovarian samples of four species with distinct fecundity types (sardine, mackerel, horse mackerel and cod), collected through national sampling programmes.

Many samples (n>600) has been sent to AUTH and IMR for histological analysis and oocyte size frequency distribution (OSFD) analysis, respectively. At present, all samples have been processed for OSFD, all mackerel and most sardine samples have been processed histologically (paraffin, haematoxylin/eosin) while an amount of sardine and mackerel samples (n~70) has been further processed in resin (DTU) and scanned in high quality photomicrographs (at IMR). The analysis of this material is currently in progress and currently focuses on investigating how spawning rhythm is reflected in ovarian dynamics, drawing evidence from sardine and mackerel as two fishes with highly contrasting OSFDs and spawning frequencies (and thereby POF degeneration patterns).

**Imaging for the analysis of plankton: EcoTaxa.** Jean-Baptiste Romagnan. Ifremer. Nantes. France

In the past 2 decades phytoplankton, zooplankton and ichtyoplankton (fish eggs) proved to be good indicators of long-term environmental changes, and important components in trophic and ecosystem studies in the context of fisheries science. This led to a renewed enthusiasm in re-analysing existing long-term plankton time series samples, and in developing high frequency, and high spatial coverage plankton and ichthyoplankton monitoring. As a consequence, the number of samples to analyse increased dramatically, and imaging instruments combined with semi-automated sample processing methods based on Machine Learning (ML) were developed as solution to optimize the time spent to assemble and elaborate this new data. However, an essential drawback remains: this data originating from imaging combined with ML must be scrutinized by experts to be scientifically qualified. This step represents a major bottleneck in the analysis process, and several solutions can be envisioned: (i) improvement of automatic identification of imaged objects by the improvement of ML methods, (ii) better estimation and handling of the errors made by ML techniques, (iii) improvement of the ergonomic of the qualification process (made by experts). EcoTaxa (Picheral *et al.*, 2017) is a recently developed web based application that bring solutions to points

(i) and (iii) by proposing an interface dedicated to plankton imaging developed on the basis of experts' feedback, combined with up to date ML methods (Convolutional Neural Network, CNN), through an open platform that promote collaborative work, and hence the quality of data.

**DEPM 2017 sardine issue in ICES 9a.** M.M. Angélico and C. Nunes. IPMA. Lisbon. Portugal

During the ACEGG group meeting, updated estimates of the sardine 2017 DEPM survey were presented. The estimates obtained for the North stratum (ICES 9aN and 8c) covered by SAREVA0317 were provided as final ones and discussed within the WG in Nov. 2017; the estimates calculated for the South and West strata (ICES 9aW and S), monitored by the PT-DEPM17-PIL survey, were unavailable at the time, and were thus presented to the group during this year's meeting. Nevertheless, the late period during which the Portuguese survey covered these waters in 2017 (especially in the West stratum where sardines were in 2017 closer to the end of/had ended spawning season) had implications on the methodology to analyse the data and calculate these estimates. This issue was discussed, and different possible analytical approaches were considered and tested during the week within the DEPM sub-group. The approach was to look at the West stratum as composed of two sub-strata, which boundaries were established based on both the distribution/abundance of eggs and the reproductive activity of the adult fish. For each of these two sub-strata, a weighing factor was attributed to calculate the mean values of the adult parameters for the West coast, with three different weighing factors having been considered (egg abundances based on the CalVET sampling, egg abundances obtained from the CUFES sampling during the acoustics surveying, sardine biomass estimates from the Acoustic PELAGO17 survey). The final analytical option considered, presented and agreed in the WG, was to use egg abundances obtained from the CUFES as weighing factors. The final estimates based on this methodology could not be available during the WG meeting, the work will be finalized shortly after, and the estimates provided to the WGHANSA in 2019.

**The use of the CUFES in acoustic surveys to estimate the egg abundance of mackerel (*Scomber scombrus*) and horse mackerel (*Trachurus trachurus*).** P. Díaz, I. González and P. Carrera (IEO, Vigo & Coruña, Spain)

For the first time in the Spanish acoustic-trawl survey series (PELACUS) and in the International Blue Whiting Spawning Survey (IBWSS) the Continuous Underway Fish Egg Sampler (CUFES, Checkley et al., 1997) was used to estimate the quantitative egg abundance of mackerel and horse mackerel. Two areas with a different sampling grid were prospected, the Porcupine Seabight (IBWSS) and the Northern Spanish waters. In Porcupine Seabight the sampled was performed during day and night time and few eggs of mackerel and horse mackerel were found. On the North Spanish waters, sampled was carried out during daytime with a total of 94315 mackerel eggs counted. Mackerel eggs without embryo (stages 1a and 1b) were sorted and counted from those with embryo in different stages of development. Around 27 % of eggs sampled had not embryo and 73 % had embryo. This presentation provides a summary of the abundance and distribution of mackerel and horse mackerel. In addition, the presentation discus the advantages of the use of CUFES as a complement to the in-formation obtained in the triennial mackerel and horse mackerel egg survey, an ICES-coordinated international survey in the north east Atlantic.

### 5.3.3 Methodological developments for comparing acoustic and DEPM indices

#### 5.3.3.1 Session on survey bias and precision

The surveys coordinated by WGACEGG use two different observation methods (acoustics and eggs) on the same resources (sardine and anchovy). The estimates derived by the different methods do not always agree. In this context, the concepts of survey precision and bias were revisited by the group and a strategy discussed for further analysis.

Bias represents a systematic error, while precision relates to data variability. Bias originates from fish behaviour interacting with the survey protocol. It may vary between years. Survey bias cannot be estimated from the survey data alone. But variation in survey bias across years can be monitored using different survey methods and in particular by combining acoustic and egg estimation methods. Even though the differences between estimates are not well understood, they can serve to construct a reliability index of the survey estimates. Also, an "ensemble" approach using the various survey indices could lead to a more robust survey index.

Another source of bias relies in the survey design. All areas should have equal sampling probability. Over sampling may lead to bias if data are not analysed properly. Stratification of the data can be a solution, depending on the situation.

By contrast, survey precision can be estimated from the survey data alone as it depends on data number and variability. Survey precision may be estimated using classical statistics or geostatistics. Classical statistics is a design-based approach, where the data locations need be randomized. This allows to estimate population abundance with no hypothesis on the surveyed population. In contrast, geostatistics is a model-based approach, where spatial autocorrelation in the data is modelled. The advantage is that survey design can be regular, which is adapted for acoustic and egg surveys. In the CRR 338 (Handbook of geostatistics in R for fisheries and marine ecology), R scripts are available for estimating survey precision for different survey designs, including regular or random designs.

#### 5.3.3.2 Comparison of egg and acoustic-based fish biomass indices

Available biomass indices derived from eggs and acoustic data for anchovy and sardine in the Bay of Biscay in spring were compared, to assess the potential presence of bias in the indices (**Fig. 5.3.3.1-4**). Linear models were fitted on the data to assess the general agreements between the indices along the series.

Acoustic and egg (CUFES) data were collected simultaneously during the PELGAS survey on the same platform. Eggs were also sampled during the same period and in the same area during the BIOMAN survey, using PairoVET nets.

Biomass indices derived from acoustic data on one hand, and from egg data collected either with PairoVET or CUFES on the other hand agreed relatively well in the case of anchovy in 2018, showing no sign of bias. Overall significant linear relationships ($R2$ = 0.73 and 0.61) were found between acoustic and egg-based indices over the series for anchovy. Biomass indices derived from acoustic and egg data also showed a relatively good agreement in the case of sardine in 2018, showing no sign of bias. Overall significant linear relationships ($R2$ = 0.69 and 0.67) were found between acoustic and egg-based indices over the series for sardine.

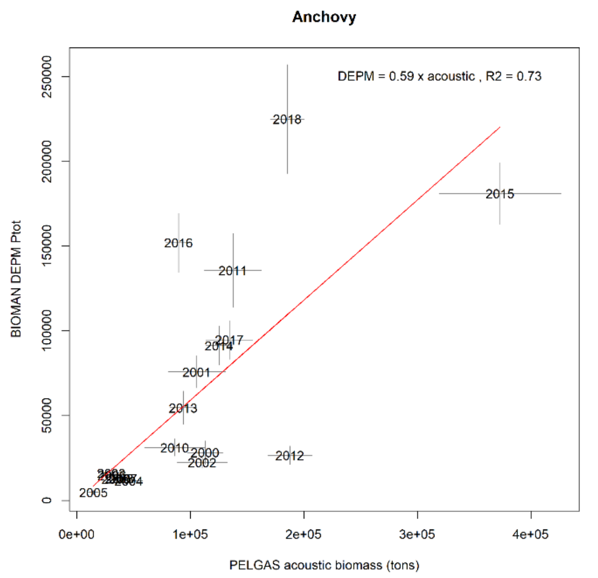



Figure 5.3.3.1: Anchovy acoustic biomass estimate (PELGAS) vs. Total daily egg production from DEPM (BIOMAN). Segments: confidence intervals around indices. Red line: linear model fit.

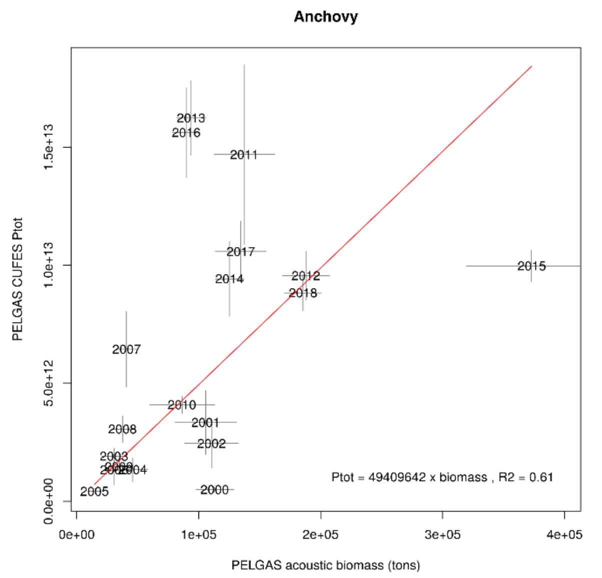



Figure 5.3.3.2: PELGAS acoustic biomass estimate vs. PELGAS number of eggs in CUFES: for anchovy. Segments: confidence intervals around indices. Red line: linear model fit.

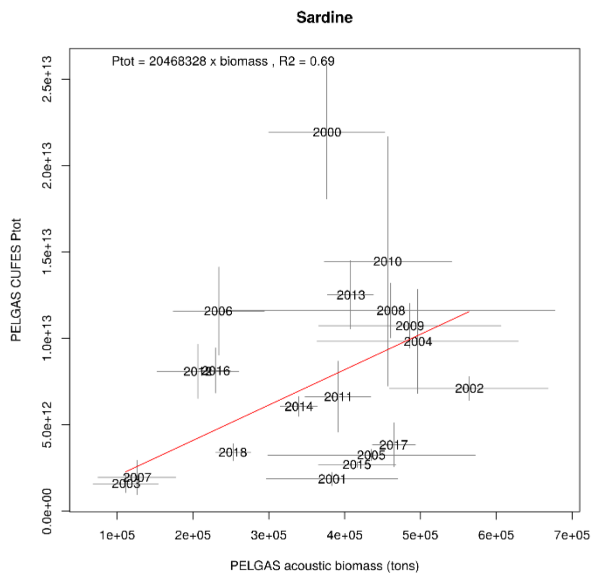



Figure 5.3.3.3: PELGAS acoustic biomass estimate vs. PELGAS number of eggs in CUFES: for sardine. Segments: confidence intervals around indices. Red line: linear model fit.

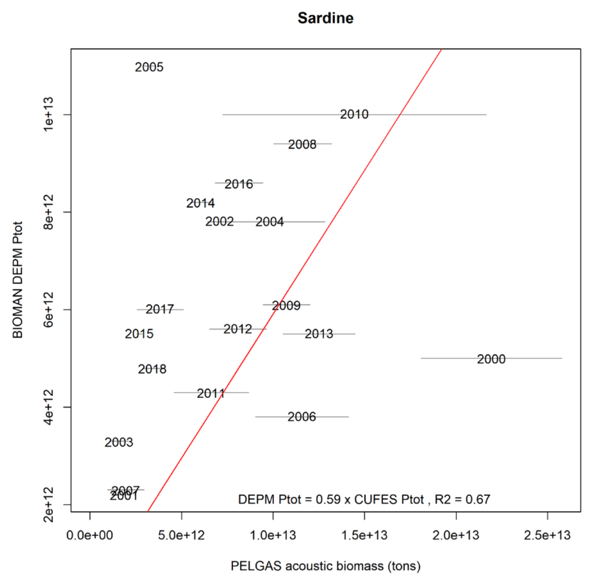



Figure 5.3.3.4: Sardine acoustic biomass estimate (PELGAS) vs. number of eggs in PairoVETs (BIOMAN) Segments: confidence intervals around indices. Red line: linear model fit.

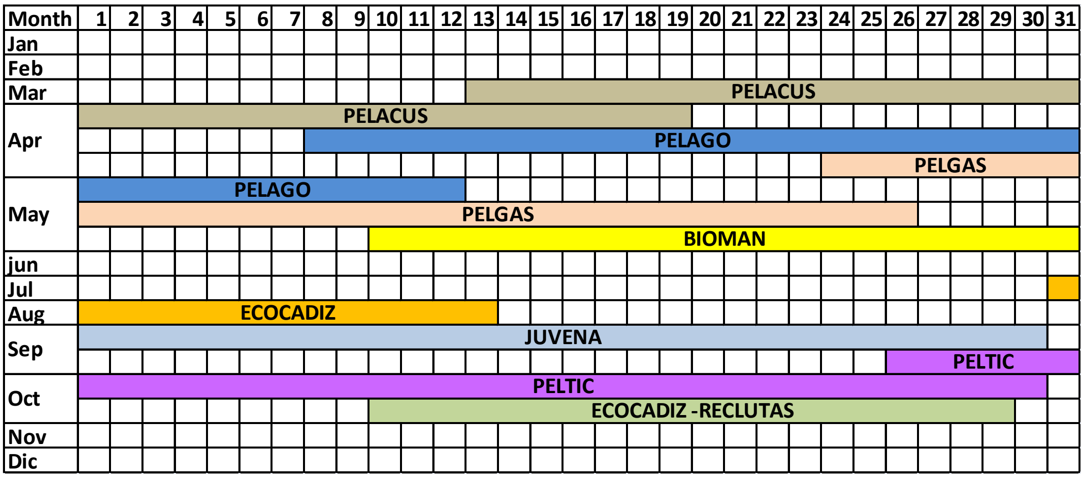
## 5.4 Suitability of CUFES data for anchovy and sardine egg production estimates in area 8 and 9

The one-dimensional vertical biophysical model for anchovy eggs distribution, developed by Petitgas *et al*. (2006), has been implemented to be applied to the CUFES data from BIOMAN survey. Fish eggs are passive particles and their vertical distribution is determined by the model as a function of egg properties (diameter, density, both kept constant in time) and water properties (density, viscosity, turbulence). Thus, the model inputs are surface wind, tidal currents and T - S and density profiles from CTD data. First test runs were applied to the CTDs stations from BIOMAN 2015 survey. The meteorological variables were taken from the Arpege model reanalysis. The work is in progress as the tests show numerical crash in relation with CTD input. The work is in progress and hope to have Ptot values derived from the CUFES and the model for November 2019.

## 5.5 Coordination and standardization of the surveys, including QAQC procedures

### 5.5.1 Survey dates and ports of call

Survey planning for 2019 is summarized in the table below:




**Acoustic surveys**

The spring acoustic surveys will be carried out following the standard methodologies defined by the WGACEGG and coordinated between IPMA, IEO and Ifremer. IPMA will survey the southern region from Cadiz to the northern border between Portugal and Galicia (PELAGO); IEO will operate off western Galicia and the Cantabrian Sea (PELACUS) and Ifremer (PELGAS) will cover the French shelf of the Bay of Biscay.

In summer, IEO will carry out the ECOCADIZ survey in the southern Spanish and Portuguese waters of the Gulf of Cadiz.

In autumn 2019, the PELTIC survey will be carried out in area demarcated by the “Mackerel box” off the Southwest of Britain (sections of subarea VII). Multidisciplinary methodologies, coordinated through two relevant survey working groups (WGACEGG and WGIPS), will be implemented as described in the Manual for International Pelagic Surveys (SIPS 9, ICES 2015).

**Autumn acoustic recruitment surveys**

JUVENA survey is coordinated between AZTI and IEO, as a result of the compromise of collaboration between both institutes in 2014. AZTI leading the assessment studies of the JUVENA series, and IEO the ecological studies, substantially increasing the planktonic sampling effort and adding new ecological-environmental objectives to the project. In 2019, it is planned to continue this collaboration in similar terms than those carried out in the past years. This year, IPMA and IEO started a common acoustic-trawl survey time series called IBERAS-JUVESAR aiming to estimate the strength of the sardine and anchovy recruitment and covering the Atlantic waters of the 9a (i.e. excluding the Gulf of Cádiz). For 2019, it is expected to shift the survey to September, beginning

October and carrying out it on board R/V Angeles Alvariño, similar to R/V Ramón Margalef. In such case, it is likely to achieve a synoptic coverage of the southern Atlantic European waters, similar to that of Spring, but with similar vessels. Any vessel and/or fishing operation effects on fish behaviour will be similar, therefore allowing for better estimates

In the Gulf of Cadiz, it is planned by IEO a recruitment survey (ECOCADIZ-RECLUTAS).

**DEPM surveys**

In 2019 the annual anchovy DEPM survey in the Bay of Biscay (BIOMAN) will take place in May conducted by AZTI, covering the usual spawning grounds at ICES 8abcd. In the same area the total daily egg production for sardine will be estimate.

The next DEPM survey to estimate the SSB of Anchovy in the Gulf of Cadiz (BOCADEVA triennial survey) will take place by IEO in July 2020. The triennial Sardine DEPM survey will take place in 2020. The region from the Gulf of Cadiz to the northern border between Portugal and Spain will be surveyed by IPMA (PT-DEMP20-PIL); IEO will cover the northwestern Iberian Peninsula and the inner part of the Bay of Biscay until 45ºN (SAREVA). And AZTI will apply the DEPM for sardine in the Bay of Biscay from 45ºN to 48ºN.

### 5.5.2 Update on WGACEGG Series of ICES Survey Protocols

The SISP report describing protocols used during the DEPM surveys coordinated within WGACEGG has been consolidated and should be submitted for publication in January 2019.

During the acoustic surveys SISP report session, acoustic cruise leaders have provided a table summarising their survey protocols in a common format. The SISP report outline has been updated to incorporate requests from PGDATA on the important information to be included in the report. Sections of the report have been assigned to lead authors who agreed to provide a first draft of the SISP report on 04/03/2019. The WGACEGG acoustic surveys SISP report will be consolidated during the 2019 meeting and submitted for publication in December 2019.

## 5.6 Development and standardization of data processing methods for DEPM and acoustic methods for surveys in Atlantic and Mediterranean waters

A training course on the EchoR R package for processing fisheries acoustics data collected during sea surveys has been given during the acoustic session. Participants included WGACEGG members and scientists from the MEDIAS group, in an attempt to standardise methodologies and software used for processing acoustic data in the Atlantic and Mediterranean areas.

Participants have been asked to share their questions and issues on EchoR usage. As no major problem was raised by EchoR users, the session consisted in a presentation of the new EchoR functionalities, including the automatic production of time series of gridded maps, and new tutorials describing the implementation of Multiple Factorial Analysis on gridded maps following the (Doray *et al.*, 2018a) methodology and of Integrated Trend Analysis using Min-Max Auto-correlation Function Analysis (MAFA) on time series of survey indices, based on (Doray et al., 2018b)'s methodology. A new EchoR module allowing to import acoustic and biotic data from the ICES acoustic and trawl database has also been presented.

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Doray, M., Hervy, C., Huret, M., and Petitgas, P. 2018a. Spring habitats of small pelagic fish communities in the Bay of Biscay. Progress in Oceanography, 166: 88–108.

Doray, M., Petitgas, P., Huret, M., Duhamel, E., Romagnan, J. B., Authier, M., Dupuy, C., et al. 2018b. Monitoring small pelagic fish in the Bay of Biscay ecosystem, using indicators from an integrated survey. Progress in Oceanog-raphy, 166: 168–188.

## 5.7 Cooperation with other WG

### 5.7.1 Response to recommendations

#### 5.7.1.1 Response to recommendation 61

All WGACEGG members agreed to adopt the ICES metadata convention for processed acoustic data and the ICES data portal for storing and publishing their acoustic trawl surveys data. IPMA representatives were however not entitled to formerly endorse this recommendation. They will request a formal approval of their institute and report the answer during the 2019 meeting.

#### 5.7.1.2 Response to recommendation 72

WGACEGG agreed to update its SISP manuals with the correct references of the WKASMSF report and include or update the conversion table for the national maturity scales.

#### 5.7.1.3 Response to recommendation 84

The PELAGO acoustic survey representatives agreed to extend it to estimate relevant pelagic species in Iberian waters beside sardine and anchovy, such as horse mackerel and chub mackerel in the future conditions permitting (equipment and vessel operation).

#### 5.7.1.4 Response to recommendation 91

WGACEGG agrees to have back-to-back meetings with WGHANSA in mid/late November. The two groups would remain independent in terms of governance and TORs. WGACEGG will decide on the location and date of its meetings. WGACEGG proposes the two groups to have a joint session on the first day of its meeting. This joint session would be devoted to the presentation of the survey results. Survey presentations could be followed through webex or physically by WGHANSA members, to allow for exchanges between the two groups on surveys events and outcomes. WGHANSA physical meeting should then take place after the WGACEGG meeting.

#### 5.7.1.5 Response to recommendation 102

WGACEGG does not coordinate any mackerel egg survey.

## 5.8 Cooperation with Advisory structures

WGACEGG has provided the WGHANSA stock assessment group with the sardine and anchovy indices listed in **section 4**.

WGACEGG has provided the WGWIDE stock assessment group with horse mackerel, boar fish, mackerel and blue whiting distribution and numbers-at-age in 9a and 8c derived from the PELACUS survey.

## 5.9 Science highlights

WGACEGG has published an ICES Collaborative Research Report (CRR) presenting the pelagic survey series for sardine and anchovy in ICES subareas 8 and 9a and their move towards an ecosystem approach (Massé et al., 2018). The CRR includes an atlas presenting the standard gridded maps of parameters on fish, environmental and megafauna produced over the 2003-2013 period by the group, as well as a first insight into the variability of the spatial distributions and habitats of anchovy and sardine in subareas 8 and 9a in spring.

WGACEGG has presented a poster at the 2018 ICES Annual Science Conference, to showcase the use of WGACEGG acoustic and egg-based survey products for monitoring anchovy and sardine populations in the European Atlantic area ecosystem (Doray et al., 2018d). This poster presented the first results of a comprehensive statistical analysis of WGACEGG gridded maps that is being conducted within the framework of the group. The objectives of this analysis are: i) to summarise the spatial and temporal patterns of the distribution of anchovy and sardine in their environment in a single statistical framework, ii) to highlight potential atypical years to monitor changes, iii) to relate changes in anchovy and sardine distribution to environmental and/or anthropic pressures.

A special issue on integrated surveys has been published in the Fisheries Oceanography journal. A total of 6 articles based on data from the PELGAS survey and published in this special issue have benefited from methodologies and exchanges developed within the WGACEGG group (Doray et al., 2018a, 2018b, 2018c; Huret et al., 2018; Lambert et al., 2018; Petitgas et al., 2018).

Two articles on the ecosystem approach to Portuguese sardine fishery management (Szalaj et al., 2018) and on the trophic role of sardine in the Portuguese continental shelf ecosystem (Veiga-Malta et al., 2018) having benefited from surveying and exchanges developed within the WGACEGG group have also been published.

A paper on target strength of skipjack tuna has been published (Boyra *et al*, 2018) which includes a review of methodologies for avoiding multiple targets. The methodologies used might be particularly relevant and applicable for TS estimation of small pelagics and is being currently applied in works on TS estimation of anchovy and pearlside in the Bay of Biscay. Two papers related to the marine mammals observed during the survey JUVENA have also been published (Louzao *et al*,2018 and Garcia *et al* 2018).

### References


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# 6 Revision to the work plan and justification

A reference to the publication of WGACEGG datasets using ICES doi's has been added to TORs a, c and h. After reviewing recent advances in the field of CUFES and PairoVET samples automated analysis using imagery, WGACEGG members have decided to add a new TOR (k) to develop the use of imagery techniques to characterise the distribution of zooplankton and possibly microplastics in areas 8 and 9, based on CUFES and/or PairoVET samples. The suitability of imagery techniques to automatically count and stage anchovy and sardine eggs for spawning biomass assessment on one hand, and to classify, count and size zooplankton organisms on the other hand will be evaluated by group members. The possibility to get useful information on microplastics distribution from CUFES and PairoVET samples using imagery will also be explored.

The publication of the DEPM and acoustic SISP manuals have been postponed to year 3 in the workplan.

# 7 Next meetings

The Year 3 meeting will take place on 18-22/11/2019 in Madrid, Spain.

## Annex 1: List of participants

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# Annex 2: Recommendations

| Recommendation | Addressed to |
|---|---|
| WGACEGG recommends the PELACUS survey to be started during the first week of April, to ensure that all coordinated spring acoustic surveys are conducted within a narrow enough time frame, to provide a synoptic coverage of areas 8 and 9 | Delegates |
| WGACEGG endorses the implementation of the IBERAS survey and recommends that it should be conducted in September, to ensure that all coordinated autumn acoustic surveys are conducted within a narrow enough time frame, to provide a synoptic coverage of areas 8 and 9 | Delegates |
| WGACEGG recommends that the Portuguese DEPM sardine survey takes place at its appropriate period (peak spawning) otherwise the utilization of the information collected to produce SSB estimates may be compromised or unusable. Moreover, the unavailability of reliable estimates from the IPMA survey precludes the utilization of the IEO DEPM estimates since WGHANSA does not consider at present geographically stratified input data. | Delegates |
| WGACEGG recommends that assessment models used by WGHANSA consider the use of geographical strata | WGHANSA |
| WGACEGG recommends that WGHANSA considers the addition of references to MSY in category 1 stock advices, for them to be included in lists of sustainably managed stocks (by, e.g., MSFD) | WGHANSA |
| WGACEGG asks the ICES data centre to provide a facility for hosting datasets (survey indices and grid maps) provided by this group, including doi's, versioning and authors list | ICES Data Centre |

# Annex 3: Survey reports – working documents

## Annex 3.1: Acoustic surveying of anchovy Juveniles in the Bay of Biscay: JUVENA 2018 Survey Report

*Please see report on next page.*

Working Document to WGACEGG at Nantes,19-23 November 2018

# Acoustic surveying of anchovy Juveniles in the Bay of Biscay:

# JUVENA 2018 Survey Report

By

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## 1. Abstract

The project JUVENA aims at estimating the abundance of the anchovy juvenile population and their growth condition at the end of the summer in the Bay of Biscay. The long-term objective of the project is to be able to assess the strength of the recruitment entering the fishery the next year. The survey was coordinated between AZTI and IEO. AZTI leaded the assessment studies and IEO leaded the ecological studies. The survey took place in two research vessels: the Ramón Margalef and the Emma Bardán. The biomass of juveniles estimated for 2018 is around 489,708 tonnes, which represents a medium high estimation, ~70 % over the average.

## 2. Materials and Methods

### 2.1 Data acquisition

The survey JUVENA 2018 took place onboard the chartered R/V Ramon Margalef and the R/V Emma Bardán, both equipped with scientific echosounders. The acoustic equipment included three split beam echo sounders Simrad EK60 (Kongsberg Simrad AS, Kongsberg, Norway; Table 1) calibrated using Standard procedures (Foote *et al.* 1987). In the Ramon Margalef, the 18, 38, 70, 120, 200 and 333 kHz transducers were installed looking vertically downwards, 6.5 m deep, at the drop keel, whereas at the R/V Emma Bardan the 38, 120 and 200 kHz transducers were installed at the hull. For acoustic data processing the Echoview software was used.

The water column was sampled to depths of 400 m. Acoustic back-scattered energy by surface unit ($S_A$, MacLennan *et al.* 2002) was recorded for each geo-referenced ESDU (Echointegration Sampling Distance Unit) of 0.1 nautical mile (185.2 m). Fish identity and population size structure was obtained from fishing hauls and echotrace characteristic using a pelagic trawl (Table 1). Acoustic data, thresholded to -60 dB, was processed using Echoview (Ifremer) for biomass estimation and the processed data was represented in maps using R. Hydrographic recording was made with CTD casts.

*Sampling strategy*

The sampling area covered the waters of the Bay of Biscay (being 8º00’ W and 48º00’ N the limits, Figure 1). Sampling was started from the Southern part of the sampling area, the Cantabrian Sea, moving gradually to the North to cover the waters in front of the French Coast. The acoustic sampling was performed during the daytime, when the juveniles are supposed to aggregate in schools (Uriarte 2002 FAIR CT 97-3374) and can be distinguished from plankton structures.

The vessels followed parallel transects, spaced 15 n.mi., perpendicular to the coast along the sampling area, taking into account the expected spatial distribution of anchovy juveniles for these dates, that is, crossing the continental shelf in their way to the coast from offshore waters (Uriarte et al. 2001).

During the summer, information from the commercial live bait tuna fishery was collected (Table 7), in order to have knowledge about the spatial distribution and relative abundance of anchovy previous to the beginning of the survey.

## Data analysis

### *Biological processing*

Each fishing haul was classified to species and a random sample of each species was measured to produce size frequencies of the communities under study. A complete biological sampling of the anchovy juveniles collected is performed in order to analyze biological parameters of the anchovy juvenile population, as the age, size or size-weight ratio. Using these and other environmental parameters we will try to obtain, in a long term, indexes of the state of condition of the juvenile population, in order to be able to improve the prediction of the strength of the recruitment.

### *Acoustic data processing*

Acoustic data processing was performed by layer echo-integration by 0.1 nautical mile ($s_A$) of the first 65 m of the water column with Movies+ software, after noise filtering and bottom correction, increasing or decreasing this range when the vertical distribution of juveniles made it necessary.

The hauls were grouped by strata of homogeneous species and size composition. Inside each of these homogeneous strata, the echo-integrated acoustic energy $s_A$ was assigned to species according to the composition of the hauls. Afterwards, the energy corresponding to each specie-size was converted to biomass using their corresponding conversion factor.

Each fish species has a different acoustic response, defined by its scattering cross section that measures the amount of the acoustic energy incident to the target that is scattered backwards. This scattering cross section depends upon specie *i* and the size of the target *j*, according to:

$$\sigma_{ij} = 10^{TS_j/10} = 10^{\{(a_i + b_i \log L_j)/10\}}$$

Here, $L_j$ represents the size class, and the constants $a_i$ and $b_i$ are determined empirically for each species. For anchovy, we have used the following TS to length relationship:

$$TS_j = -72.6 + 20 \log L_j$$

The composition by size and species of each homogeneous stratum is obtained by averaging the composition of the individual hauls contained in the stratum, being the contribution of each haul weighted to the acoustic energy found in its vicinity (2 nm of diameter). Thus, given a homogeneous stratum with M hauls, if $E_k$ is the mean acoustic energy in the vicinity of the haul *k*, $w_i$, the proportion of species *i* in the total capture of the stratum, is calculated as follows:

$$w_i = \sum_j w_{ij} = \sum_j \left( \frac{\sum_{k=1}^{M} \left( q_{ijk} \cdot E_k \Big/ Q_k \right)}{\sum_{k=1}^{M} E_k} \right).$$

Being $q_{ijk}$ the quantity (in mass) of species *i* and length *j* in the haul *k*; and $Q_k$, the total quantity of any species and size in the haul *k*.

In order to distinguish their own contribution, anchovy juveniles and adults were separated and treated as different species. Thus, the proportion of anchovy in the hauls of each stratum ($w_{ij}$) was multiplied by a age-length key to separate the proportion of adults and juveniles. Then, separated $w_i$ were obtained for each.

Inside each homogeneous stratum, we calculated a mean scattering cross section for each species, by means of the size distribution of such specie obtained in the hauls of the stratum:

$$\langle \sigma_i \rangle = \frac{\sum_j w_{ij} \sigma_{ij}}{w_i}.$$

Let $s_A$ be the calibration-corrected, echo-integrated energy by ESDU (0.1 nautical mile). The mean energy in each homogeneous stratum, $E_m = < s_A >$, is divided in terms of the size-species composition of the haul of the stratum. Thus, the energy for each species, $E_i$, is calculated as:

$$E_i = \frac{w_i \langle \sigma_i \rangle E_m}{\left( \sum_i w_i \langle \sigma_i \rangle \right)}$$

Here, the term inside the parenthesis sums over all the species in the stratum. Finally, the number of individuals $F_i$ of each species is calculated as:

$$F_i = H \cdot l \frac{E_i}{\langle \sigma_i \rangle}$$

Where *l* is the length of the transect or semi-transect under the influence of the stratum and *H* is the distance between transect (about 15 n.mi.). To convert the number of juveniles to biomass, the size-length ratio obtained in each stratum is applied to obtain the average weight of the juveniles in the stratum:

$$< W_i > = a \cdot < L_i >^b$$

Thus, the biomass is obtained by multiplying $F_i$ times $< W_i >$.

## 3. Results

### Checking and calibrations

Calibration of the EB was performed in Vigo during the first days of the survey following the sphere method (Foote et al. 1987). The calibration of the RM was done inside the Bilbao harbor The inter-ship calibration between EB and RM was performed the September 30$^{h}$ along a 40 nautical miles long transect over a pure juvenile distribution. The intercalibration analysis of the data registered by EB and RM showed no substantial collection bias. Therefore, no correction was applied on the recorded acoustic data was.

### Sampling coverage

The survey JUVENA 2018 took place between the 31st of August and 30th of September (see Table 2). The survey sampled around 2300 n.mi. that provided a coverage of about 35,000 n.mi.$^2$ along the continental shelf and shelf break of the Bay of Biscay, from the 8º00' W in the Cantabrian area up to 48º 00' N at the French coast (Figure 1). Seventy-four hauls were done during the survey to identify the species detected by the acoustic equipment, 56 of which were positive for anchovy (Figure 2, Tables 3, 4, 5 and 6).

The survey was covered by both vessels in coordination, in the Spanish region both vessels followed alternate transects, while in the French part they concentrated the sampling effort of each vessel in the most appropriate areas according to their efficiency: this is, oceanic and slope waters for the RM and continental shelf for the smaller pelagic trawler EB (Figure 1).

### Spatial Distribution

This year, as usual, we have found anchovy distributed along two different strata: a pure juvenile anchovy stratum and a mixed juvenile-adult stratum (Figure 4):

- **Pure juvenile stratum**: In this stratum, anchovy was located in the uppermost part of the water column forming the typical superficial aggregations of pure juvenile anchovy (Figure 4), mixed in occasions with smaller proportions of juvenile horse mackerel and gelatinous species. In order to simplify description, we can divide this stratum in two areas, Cantabric and French.
    - **Cantabric sub-stratum**: in this area, anchovy juveniles were extended both on and off the shelf, from 8º00' W to 1º40' W (Figure 4). Mean sizes ranged between 3.5 and 6.5 cm in this area (Figure 3). The vertical distribution of juvenile anchovy extended from 5 to 50 m depth.

- **French sub-stratum**: this area was extended in front of the Southern French Coast (to the South of 45ºN), from coastal areas to the slope waters. Sizes in this area varied between 6 and 9 cm (Figure 3). The superficial aggregations of anchovy were composed by a majority of juvenile anchovy, mixed with small quantities of horse mackerel and jellyfish.

- **Mixed stratum**: Anchovy size in this stratum was bigger, between 11 and 13 cm (Figure 3), a mix of adult and juvenile (Figure 4), and was detected in schools close to the bottom, mixed also with superior proportions of other species (Figure 2).
- **Garonne:** Around the plume of the Gironde river, a positive area was found extending from the coast to about 100 m isobath. Here, anchovy included both adults and juveniles, and was found mixed with sardine, spratt and horse mackerel plus other species (Figure 2), distributing along the whole water column. The sizes ranged from 9 to 12 cm (Figure 3).

**Juvenile anchovy biomass estimations**

The biomass of juveniles estimated for this year is 489,708 tones (Table 7). This value represents a medium high value, well above the average in the temporal series (Figure 6). The area of distribution of juvenile anchovy this year was also among the highest in the temporal series, (Figure 6, Table 8). The mean size of anchovy was 6.3 cm long, less than the average (Figure 3). As usual, most of this biomass was located off-the-shelf or in the outer part of the shelf (Figure 4, Table 7) in the first layers of the water column.

The biomass estimated foresees a high recruitment of anchovy for next year (Figure 7). The index of juvenile anchovy provided by JUVENA will be used to update the assessment of anchovy in the Bay of Biscay based on the CBBM (ICES, 2015).

**Predators observation in JUVENA 2018**

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A total of 2118 observations periods (legs) were performed, travelling a total of 2811 km. We recorded a total of 5258 seabirds, 2540 cetaceans, 164 of other marine wildlife, 156 marine debris, 246 of human activities and 108 of landbirds (Table 1).
Regarding marine mammals, we observed 4 different species and the spatial distribution of the most abundant species can be observed in Figure O2. The most abundant species was the common dolphin with 90 sightings (group size = 9.86 ± 18.16, a total of 887 individuals), followed by the fin whale with 41 sightings (group size = 1.59 ± 0.77, a total of 65 individuals) and the stripped dolphin with 10 sightings (group size = 25.6 ± 22.15, a total of 256 individuals). We also recorded 1 sighting of Cuvier´s beaked whale. Common dolphins were specially abundant in the northern sector of the French continental shelf, in contrast to fin whales and striped dolphins that were mainly present over over the oceanic areas of the inner Bay of Biscay (Figure O2).

Regarding seabirds, we observed 18 different species and the spatial distribution of the most abundant species can be observed in Figures 3 and 4. The most abundant species (> 20 sightings) was the northern gannet with 281 sightings (group size = 1.25 ± 0.64, a total of 352 individuals), followed by great shearwater with 252 sightings (group size = 4.06 ± 13.42, a total of 1022 individuals). The sooty shearwater was recorded in 51 sightings (group size = 1.27 ± 0.67, a total of 65 individuals), followed by the lesser black-backed gull with 50 sightings (group size = 3.28 ± 12.26, a total of 164 individuals), the great skua with 35 sightings (group size = 1.09 ± 0.37, a total of 38 individuals) and the Sabine's gull with 23 sightings (group size = 10.87 ± 18.47, a total of 250 individuals) (Table 2). We also observed European storm-petrels, yellow-legged gulls, Balearic shearwaters, Manx shearwaters, great cormorants, great black-backed gulls, common terns, Artic skuas, northern fulmars, European herring gulls, pomarine skuas and sandwich terns (Table 2).

Northern gannets were widely distributed over the study area with aggregations scattered over the French continental shelf in the northern sector and aggregated in coastal areas in the southern sector (Figure O3a, O3b). The great shearwater was mainly present in the oceanic area of the Bay of Biscay and scattered over the northern French continental shelf (Figure O3c), whereas the sooty shearwater was present mainly in coastal areas of the southern sector and the continental shelf of the northern sector (Figure O3d). The lesser black-backed gull showed different patterns in the northern and southern sectors of the study area with scattered individuals over the continental shelf and aggregated in the coastal sector, respectively (Figure O4a,b). The great skua was more present in the French continental shelf (Figure O4c), whereas Sabine's gulls were mainly concentrated in the area of influence of the Garonne River (Figure O4d).

Regarding marine debris and human activities, we observed 4 types of marine debris and 11 different activities/items of human activities (Table 2). The spatial distribution of the most abundant can be observed in Figure O5. The main marine debris recorded were plastic trashes with 52 sightings (group size = 1.1 ± 0.41, a total of 57 items), followed by fishing trash, general trash, and unnatural wood. Plastic trashes were mostly found in the southern sector of the study area (Figure O5a).

Concerning human activities, the activities with the highest number of sightings were the trawlers with 33 sightings (group size = 1.15 ± 0.44, a total of 38 items), followed by fishing buoys with 27 sightings (group size = 1.07 ± 0.27, a total of 29 vessels), and tankers with 13 sightings (group size = 1.0 ± 0, a total of 13 vessels)(Table 2). Trawlers were mainly present over the French continental shelf (Figure O5b), whereas fishing buoys and tankers were observed scattered over the study area Figure O5c and 5d).

## Conclusions

- Good survey spatial coverage
- Good general performance of the equipment and different acoustic configurations for different tasks-scenarios.
- The survey maintains or even increases its recently acquired ecological scope
- The biomass estimate of this year (489,708 tonnes) is a medium high abundance, about 70 % over the average of the JUVENA series.
- Since the year 2014, the JUVENA index is used as an input in the new CBBM so the typical log-log correlations between juvenile and recruitment indices are no longer valid.
- The juvenile abundance value foresees a medium-high recruitment level for next year.

## 4. Acknowledgements

This project is co-funded by the "Dirección de Innovación y Desarrollo Tecnológico, Viceconsejería de Política e Industria Alimentaria, Dpto.Agricultura, Pesca y Alimentación", of the Basque Government and the "Secretaría General del Mar, Ministerio de Agricultura, Alimentacion y Medio Ambiente" of the Spanish Government, seeking for improving the scientific advice for management of this population. We acknowledge both for their support.

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# 6. Figures

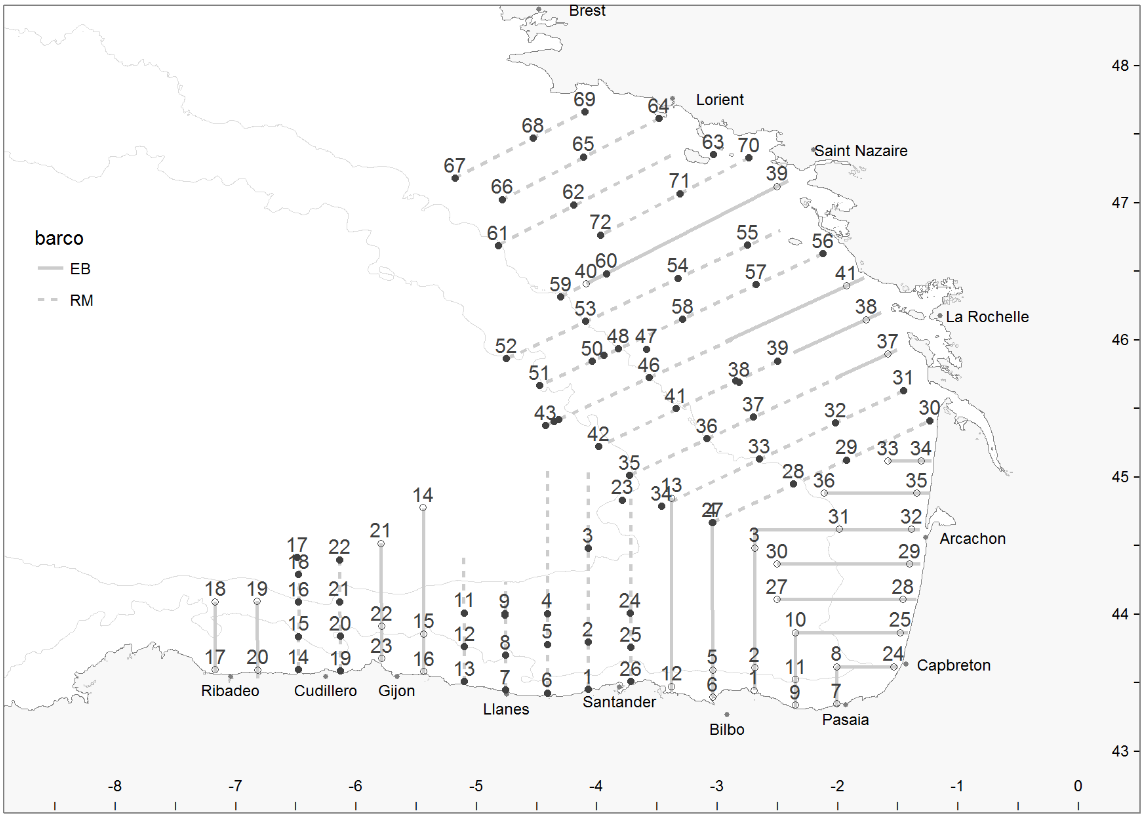



**Figure 1.** Visited transects and stations of hydrography/plankton.

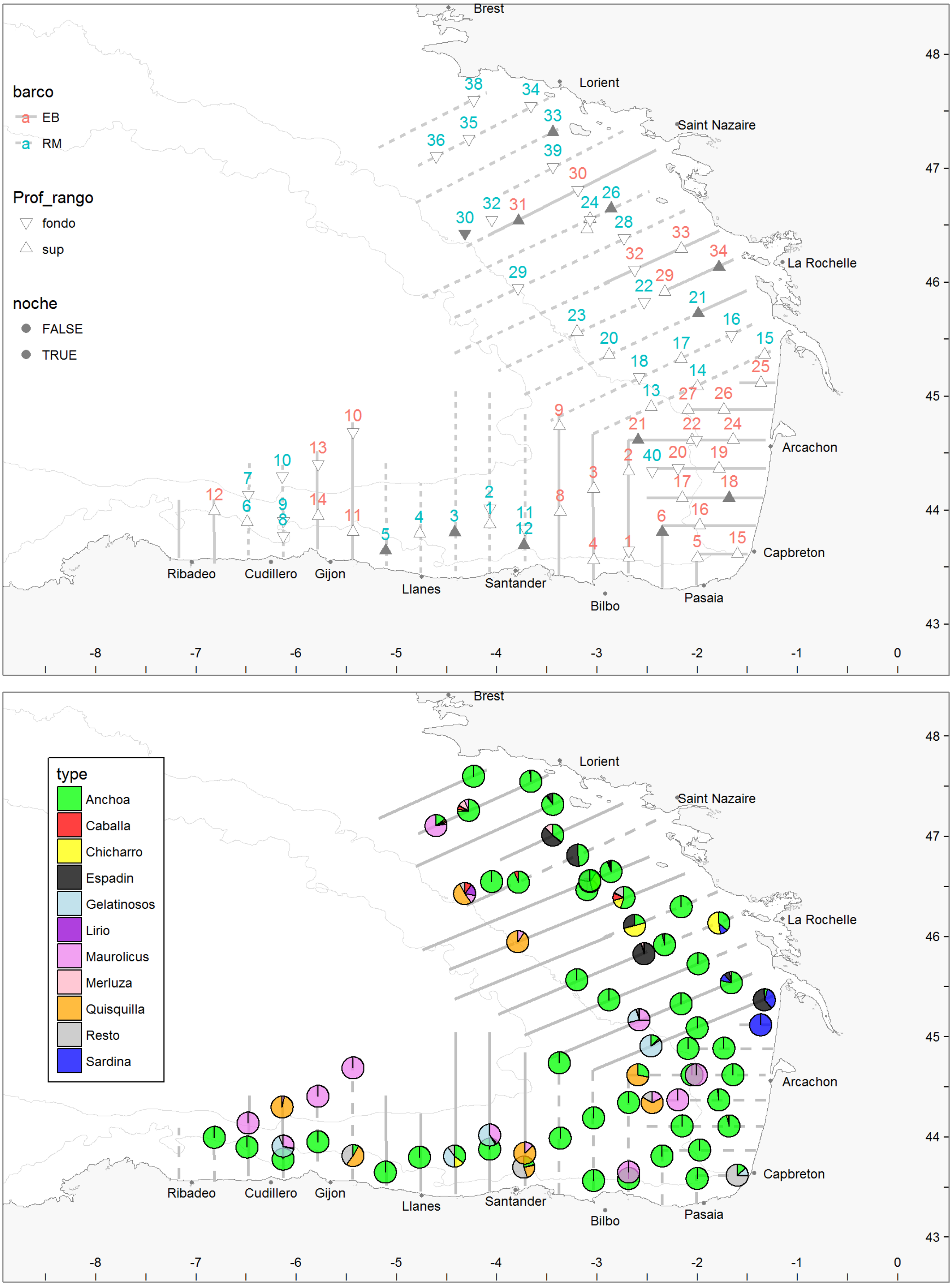



**Figure 2.** Top panel: position of the fishing stations. Hauls performed by RM are numbered from 9001 to 9034 and the transects are marked with dashed lines; hauls performed in the EB are numbered from 9201 to 9244 and the transects are marked with solid lines. Bottom panel: Species composition of the hauls.

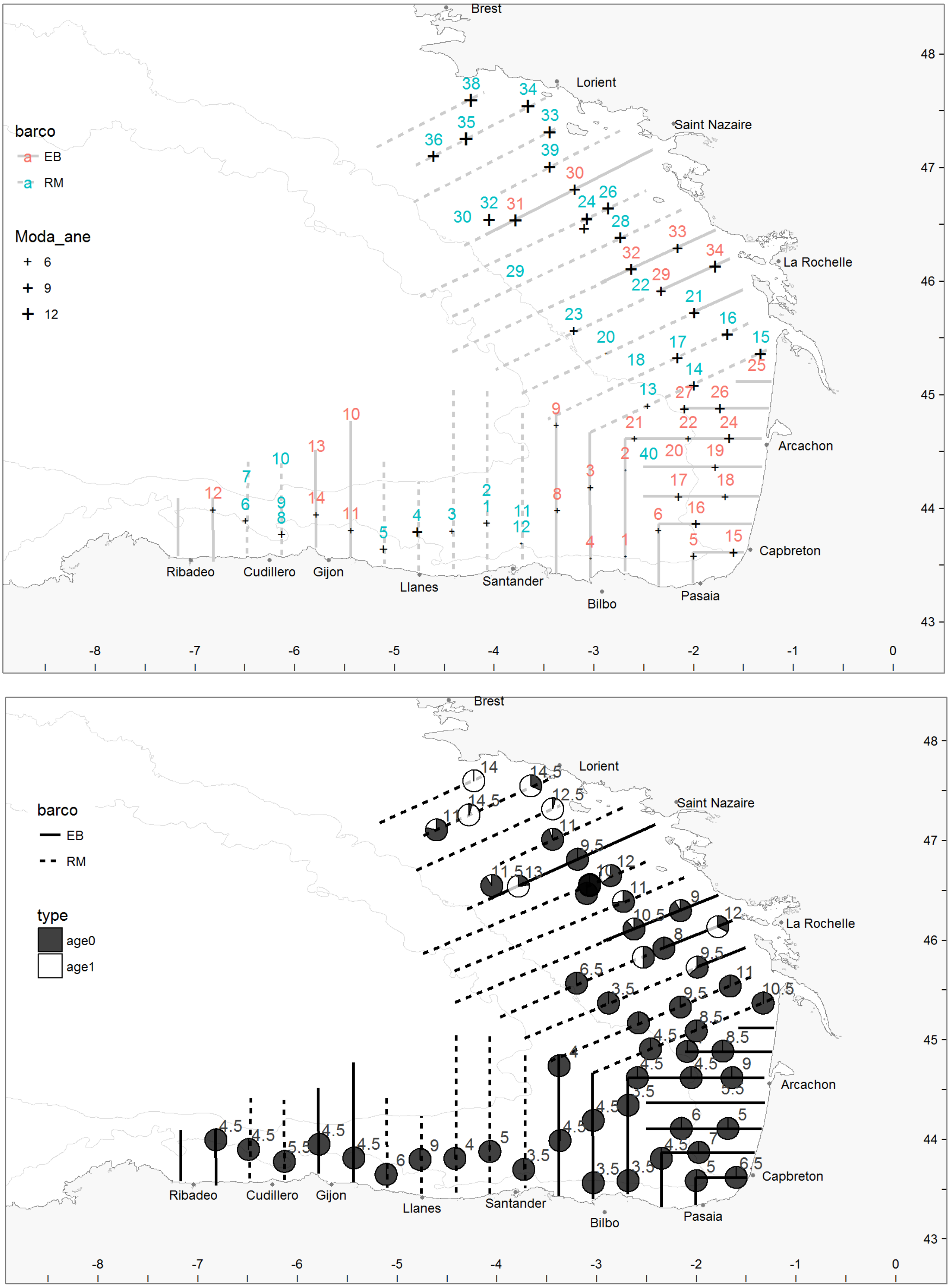
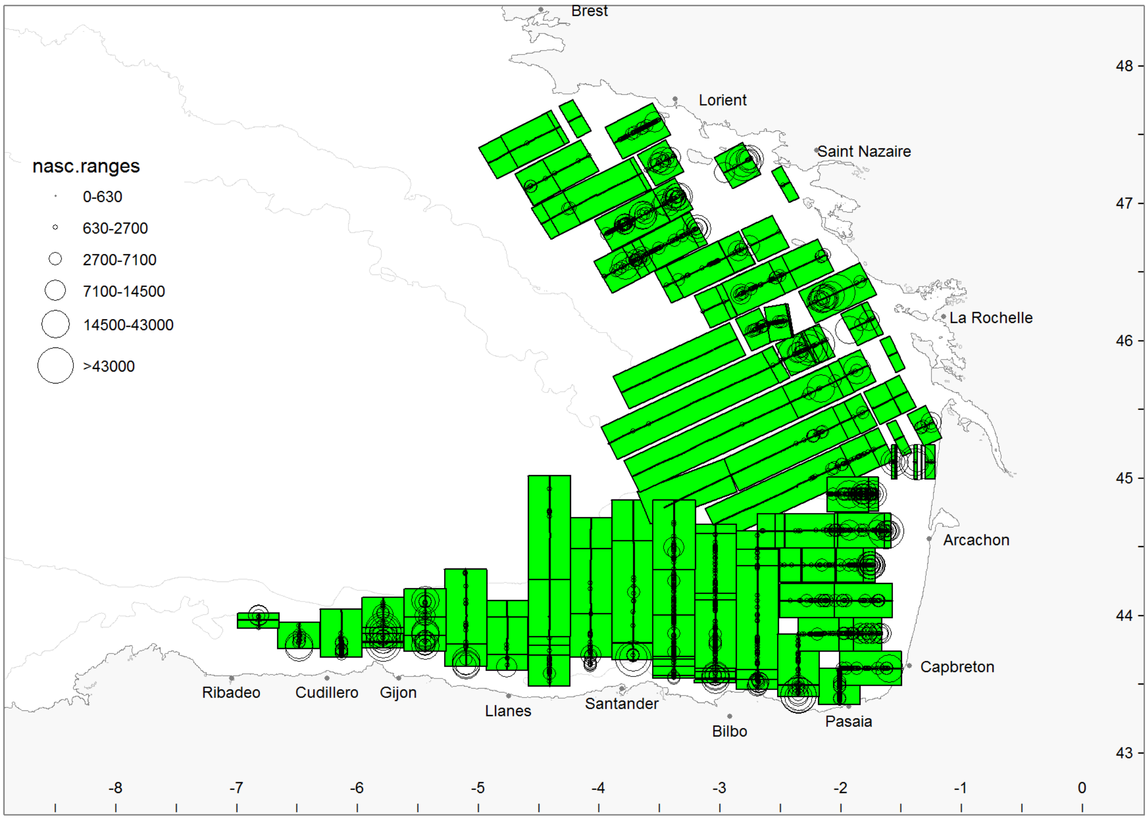



**Figure 3: Top:** Size of anchovy in the positive anchovy hauls. The size of the crosses is proportional to the mode of the Standard length of the captured anchovy. Bottom: The pie charts show the percentage of juveniles (black) and adults (white) in the fishing hauls.


nasc.ranges
0-630
630-2700
2700-7100
7100-14500
14500-43000
>43000
Brest
Lorient
Saint Nazaire
La Rochelle
Arcachon
Capbreton
Pasaia
Bilbo
Santander
Llanes
Gijon
Cudillero
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-3
-2
-1
0

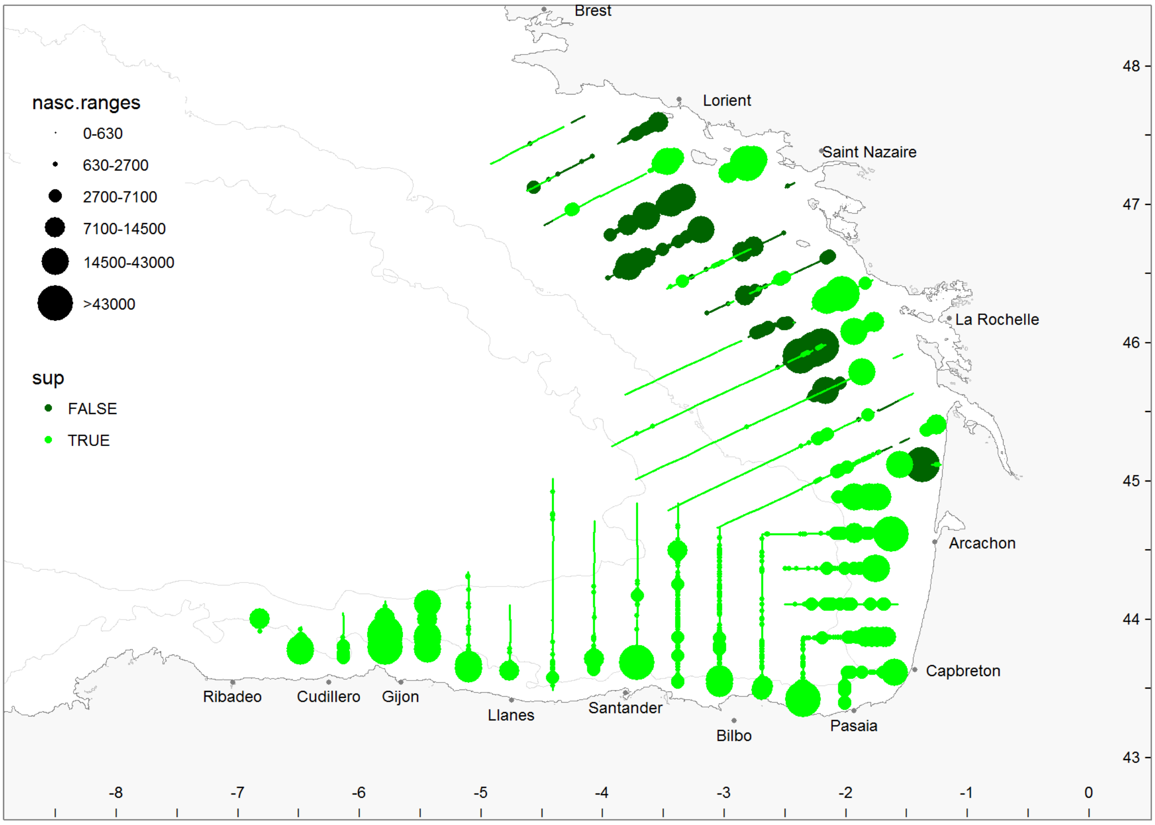



**Figure 4:** Top: Echointegration strata of anchovy. The diameter of the bubbles represents acoustic backscattering (NASC) of anchovy. Bottom: Acoustic backscattering of anchovy near the surface (light green) and near the bottom (dark green).

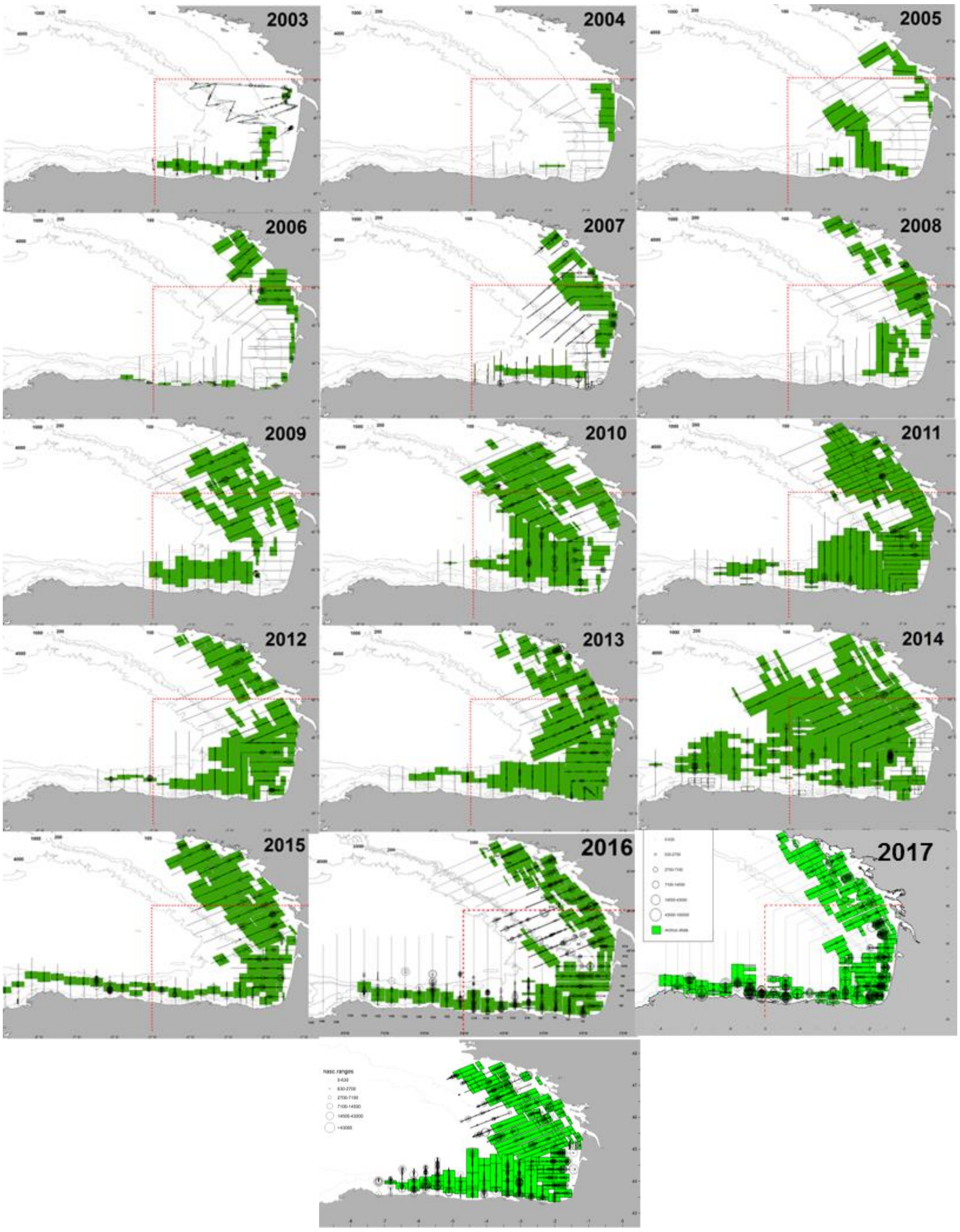



**Figure 5:** Positive area of presence of anchovy and total acoustic energy echo-integrated (from all the species) for the whole temporal series. The area delimited by the dashed line is the minimum or standard area used for inter-annual comparison.

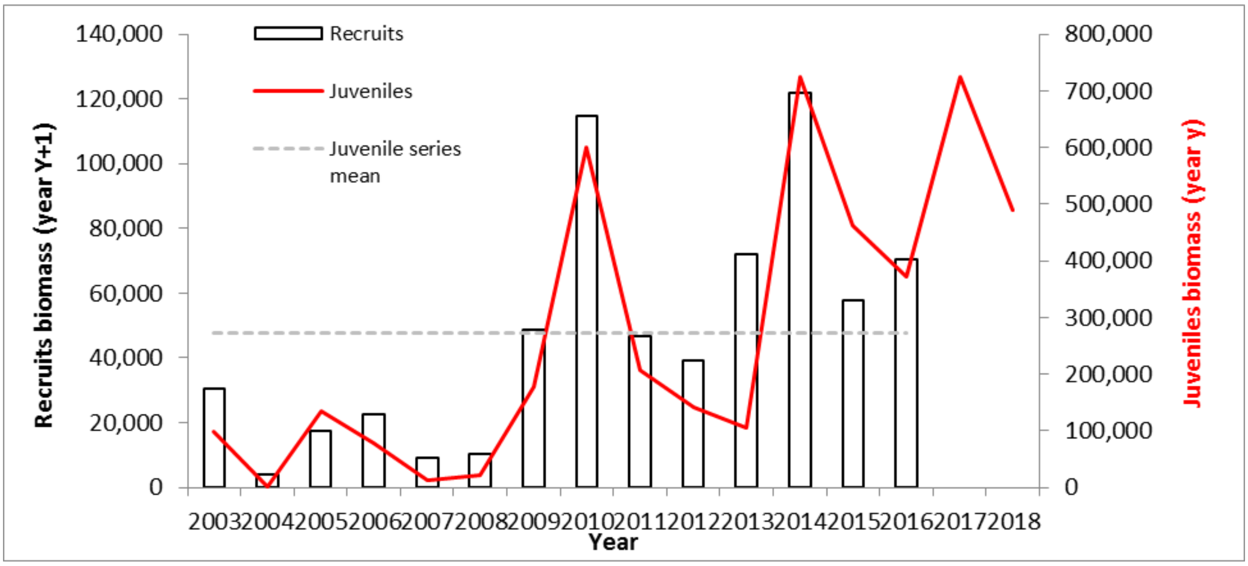



**Figure 6:** Temporal series of the estimated abundances of anchovy juveniles (blue) against the CBBM synthetic estimated abundances of age 1 anchovy next spring (red), based on PELGAS and BIOMAN surveys plus the catches.

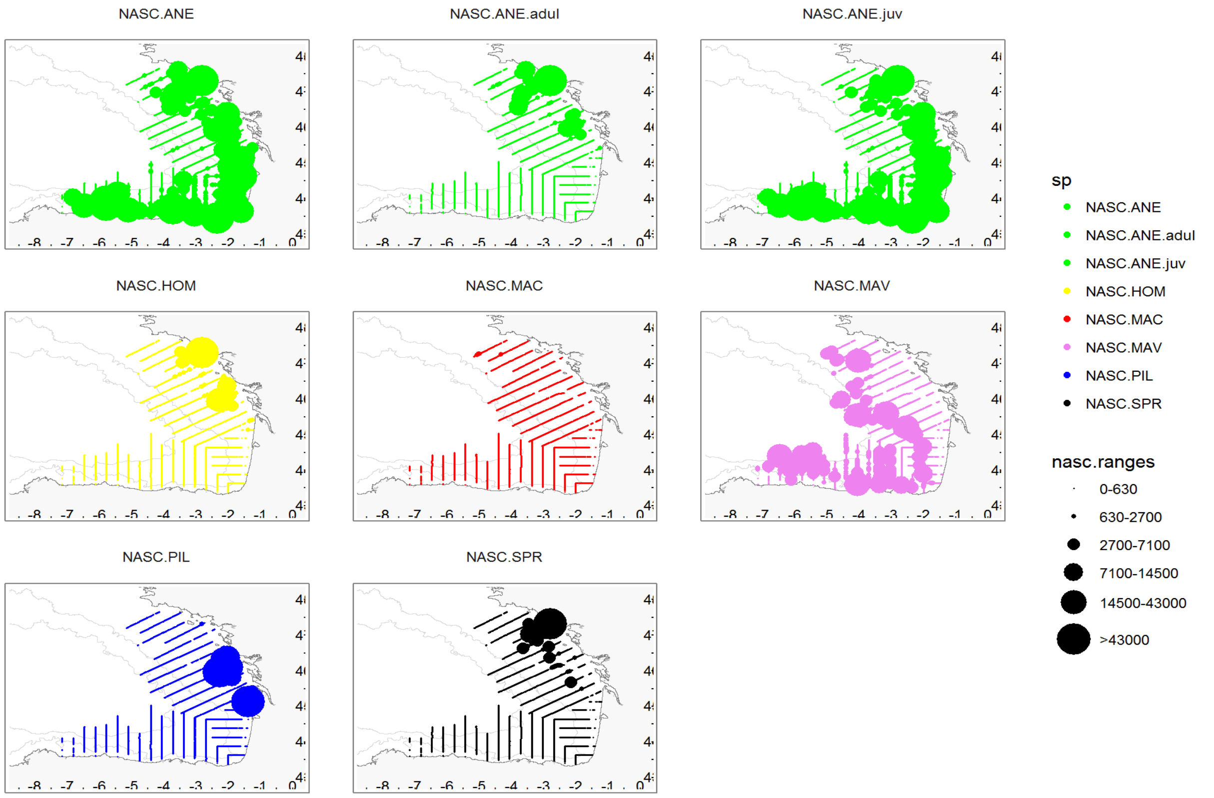



**Figure 7:** Temporal series of the spatial distribution of pelagic species assessed during JUVENA survey this year.

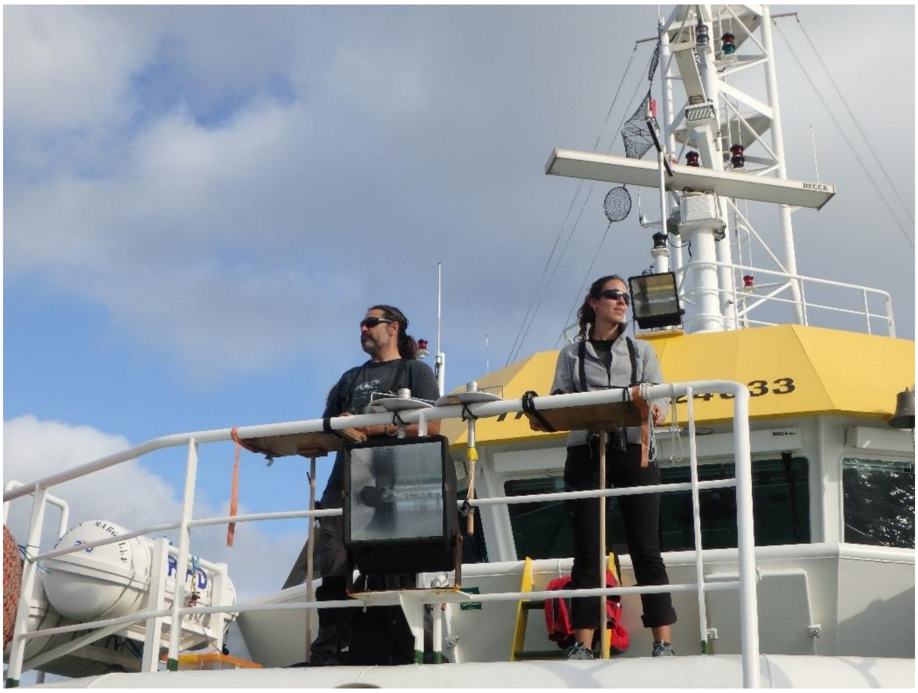


**Figure O1**. Observation platform onboard R/V Ramón Margalef showing observers activity.

(a) (b)

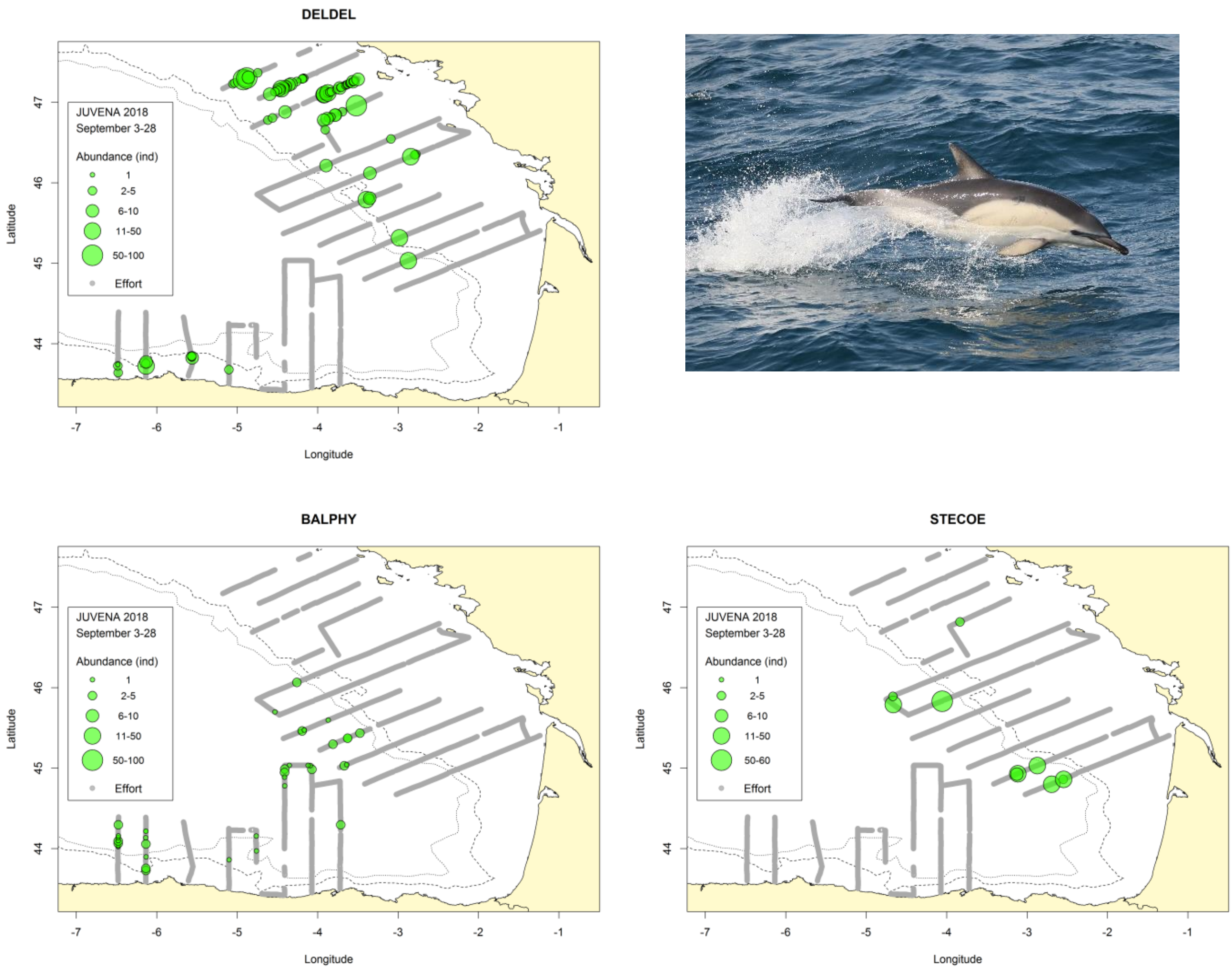



**Figure O2**. Distribution of the most abundant marine mammal species during JUVENA 2018, (a,b) common dolphins, (c) fin whales and (d) striped dolphins. Grey points represent the effort while the size of the green circles is proportional to observed abundances. The dotted and solid lines represent the isobaths of 200 m and 1000 m, respectively. See Table 2 for acronyms.

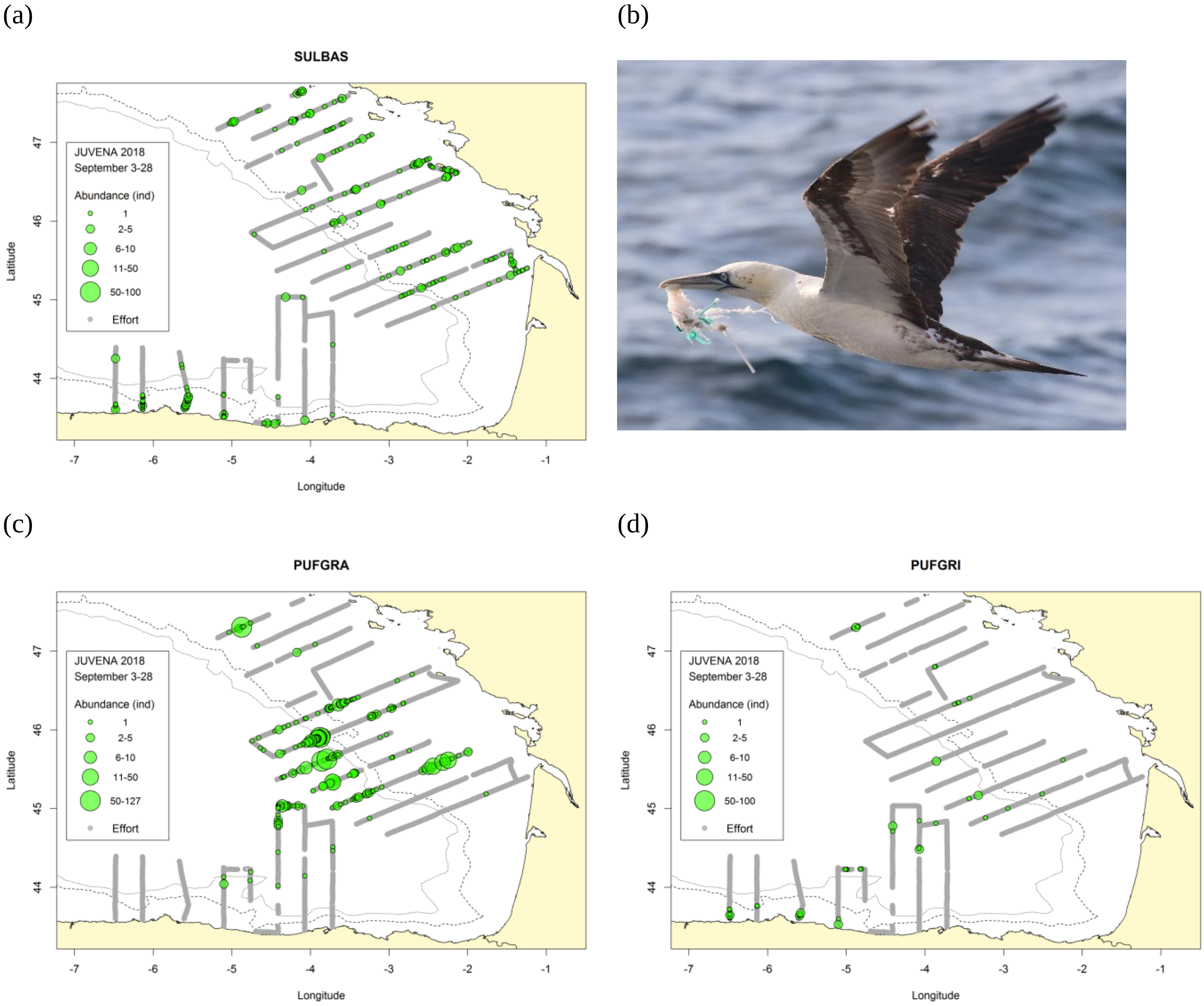



**Figure O3**. Distribution of the most abundant seabird species during JUVENA 2018 such as (a,b) northern gannets, (c) great shearwaters and (d) sooty shearwaters. Grey points represent the effort while the size of the green circles is proportional to observed abundances. The dotted and solid lines represent the isobaths of 200 m and 1000 m, respectively. See Table 2 for acronyms.

(a) (b)

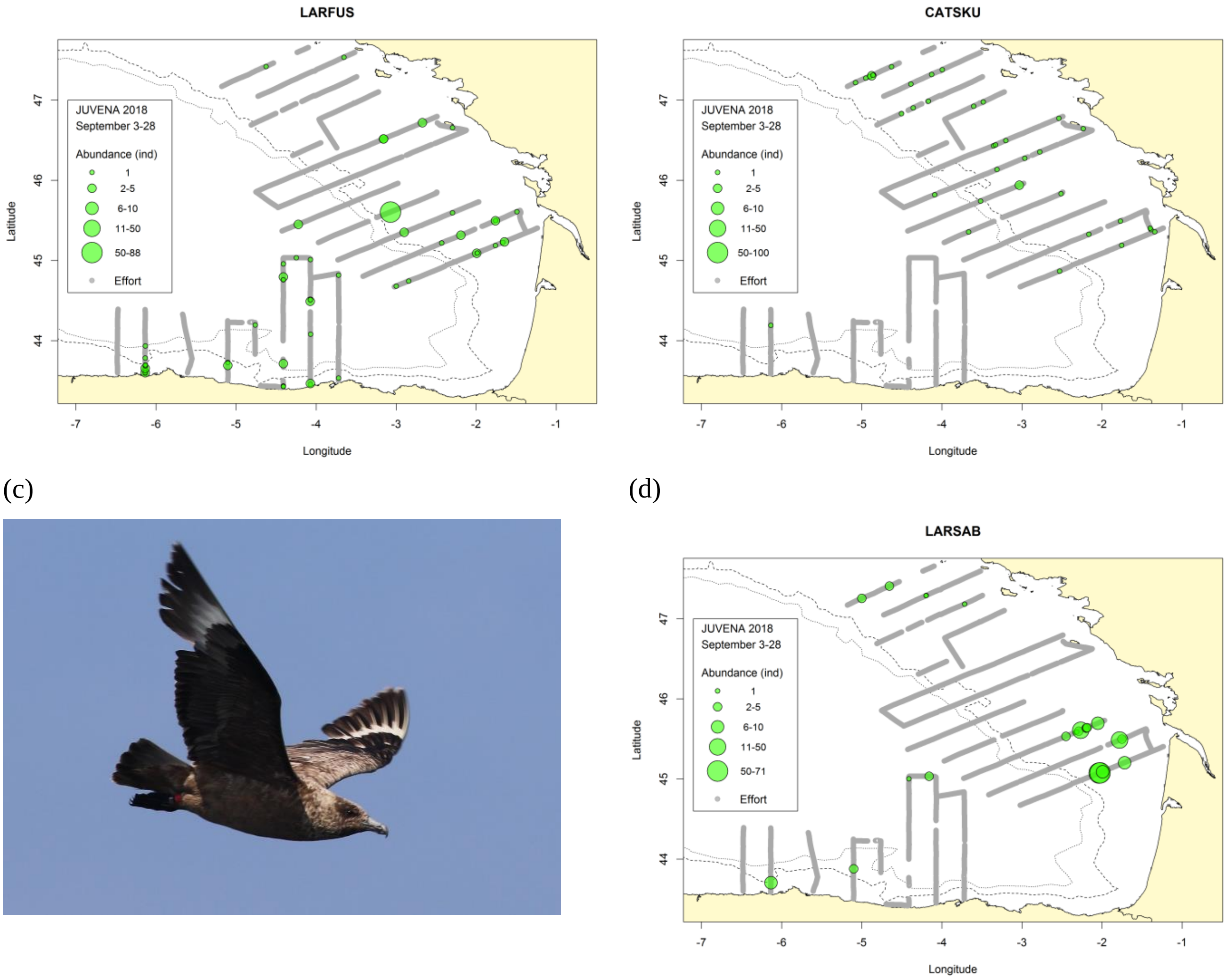
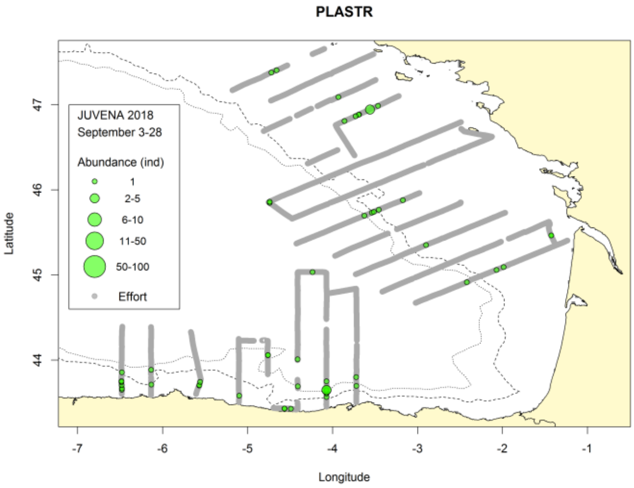
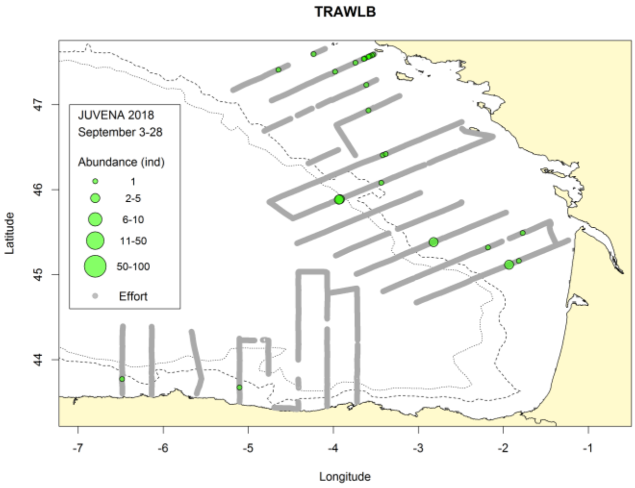


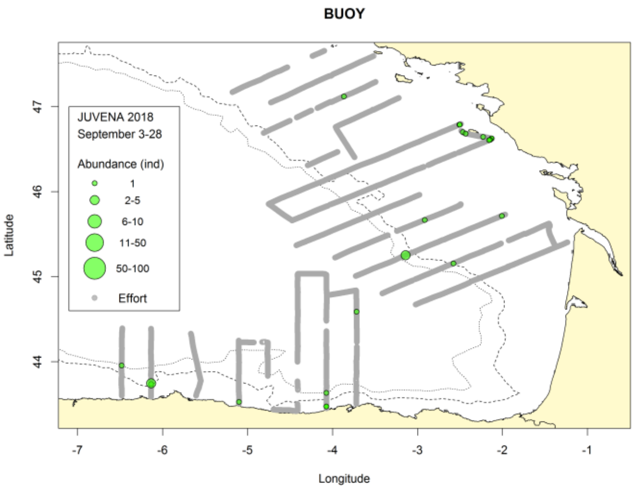

**Figure O4**. Distribution of the most abundant seabird species during JUVENA 2018 such as (a) lesser black-backed gulls, (b,c) great skuas and (d) Sabine's gulls. Grey points represent the effort while the size of the green circles is proportional to observed abundances. The dotted and solid lines represent the isobaths of 200 m and 1000 m, respectively. See Table 2 for acronyms.

(b)




(c)




(d)

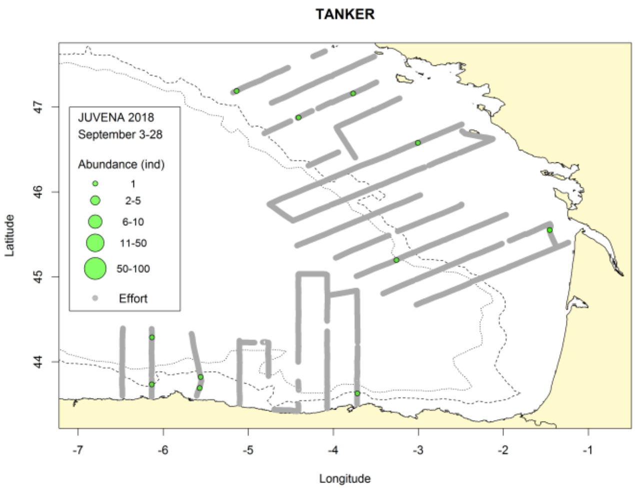



**Figure O5**. Distribution of the most abundant human activities during JUVENA 2018 such as (a) plastic trash, (b) fishing buoys, (c) merchant ships and (d) longliners. Grey points represent the effort while the size of the green circles is proportional to observed abundances. The dotted and solid lines represent the isobaths of 200 m and 1000 m, respectively. See Table 2 for acronyms.

# 7. Tables

**Table 1**:
Dimensions of the two vessels and installed equipment onboard

| | R/V Ramón Margalef | R/VEmma Bardán |
|---|---|---|
| **Echosounder** | Simrad EK60, 38, 70, 120, 200 y 333 kHz | Simrad EK60, 38, 120 y 200 kHz |
| **Multibeam Echosounder** | Simrad ME70 | No |
| **Fishing gear** | pelágico (15 m abertura vertical)<br>puertas Polyice Apollo<br>malla: 8 mm de lado | pelágico (15 m abertura vertical)<br>puertas Polyice Apollo<br>malla: 4 mm de lado |
| **Fishing gear Echosounder** | Simrad FE70 | Scanmar Trawl Eye |
| **Gear geometry** | Depth sensor Scanmar | Simrad ITI: depth/temp and door opening sensors |
| **Hidrography** | **CTD-Roseta** CTD SeaBird SBE25 with fluorimeter Turner Scufa, Roseta SeaBird SBE32 with 12 Niskin-type bottels (SBE) de 5l.<br>**Red WP2**: Double ring net, 35 cm diameter each, 200 µm mesh size<br>**Red Bongo:** Double ring net, 60 cm diameter each, 500 µm mesh size. Flux control by fluorometer GO. Real time depth monitoring by acoustic sensor (Scanmar). Salinity temperture and fluorescence recording during the trawl with CTD RBR XR-420.<br>**Red Bongo-Mik**: Net combining 35 cm 333 µm Bongo, inside a square Mik-type net of 120 cm side, 1000 µm mesh size. Net monitoring same as withe the Bongo (above).<br>**Termosalingraph-Fluorimeter:** Continuous sampler of superficila wáter for salinity, temperatura and fluoresncence. | **CTD SeaBird SBE25** with fluorimeter , oxímeter y pH-meter<br><br>**Red WP2**: doublé ring net, of 35 cm diameter each, 200 µm mesh size |

**Table 2**:
Schedule of the survey

| Activity | Harbor | Date | Notes |
|---|---|---|---|
| Instalation RM | Pasaia | 01/09/2018 | |
| Setup RM | Bilbao | 02/09/2018 | Equipment testing. Calibration. |
| Setup EB | Vigo | 31/08/2018 | Calibration / Gear testing. |
| Start survey RM | | 03/09/2018 | |
| Start survey EB | | 02/09/2018 | |
| Escale EB | | 11-12/09/2018 | |
| Escale RM | Pasaia | 10/09/2018 | |
| Escale RM | Gijón | 19/09/2018 | |
| RCAN RM (Radiales del Cantábrico) | | 22-23/09/2018 | |
| Escale EB | Pasaia | 19-22/09/2018 | Bad weather. Gasoil |
| End of survey RM | Pasaia | 30/09/2018 | Intercalibraton |
| End of survey EB | | 30/09/2018 | Intercalibration |

**Table 3:**
Relation of fishing catches performed by Ramon Margalef (90xx) and Emma Bardan (92xx).

| ST. | DATE (yyyymmdd) | TIME | LAT (Minutes Hex.) | LONG (Minutes Hex.W) | ICES | LAT (Degrees) | LONG (Degrees) | E_k (m2/ml2) | NIGHT HAUL | FISHING DEPTH (m) | ESTIMATED CATCH (kg) | DEPTH (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9001 | 20180903 | 13:59 | 43º52'29 | 4º04'09 | 16E5 | 43.87 | -4.07 | 465.4 | 0 | 10 | 7.0 | 3000 |
| 9002 | 20180903 | 17:01 | 44º00'84 | 4º04'10 | 17E5 | 44.01 | -4.07 | 605.4 | 0 | 110 | 3.0 | 3000 |
| 9003 | 20180903 | 21:37 | 43º47'88 | 4º24'65 | 16E5 | 43.80 | -4.42 | 22.5 | 1 | 9 | 5.0 | 1000 |
| 9004 | 20180905 | 16:56 | 43º47'18 | 4º45'99 | 16E5 | 43.79 | -4.77 | 216.9 | 0 | 9 | 15.7 | 900 |
| 9005 | 20180906 | 22:07 | 43º38'13 | 5º06'38 | 16E4 | 43.64 | -5.11 | 3013.2 | 1 | 9 | 60.8 | 148 |
| 9006 | 20180907 | 11:44 | 43º53'20 | 6º29'21 | 16E3 | 43.89 | -6.49 | 108.7 | 0 | 11 | 11.1 | 800 |
| 9007 | 20180907 | 16:26 | 44º07'82 | 6º28'84 | 17E3 | 44.13 | -6.48 | 1.8 | 0 | 80 | 0.5 | 4000 |
| 9008 | 20180908 | 9:41 | 43º46'35 | 6º07'74 | 16E3 | 43.77 | -6.13 | 1436.3 | 0 | 64 | 21.8 | 500 |
| 9009 | 20180908 | 13:00 | 43º53'78 | 6º07'99 | 16E3 | 43.90 | -6.13 | 922.6 | 0 | 521 | 1.6 | 700 |
| 9010 | 20180908 | 18:21 | 44º17'27 | 6º08'11 | 17E4 | 44.29 | -6.14 | 922.6 | 0 | 464 | 90.7 | 4500 |
| 9011 | 20180909 | 16:42 | 43º49'75 | 3º42'65 | 16E6 | 43.83 | -3.72 | 0.9 | 0 | 140 | 25.0 | 3000 |
| 9012 | 20180909 | 22:15 | 43º41'56 | 3º43'81 | 16E6 | 43.69 | -3.73 | 4331.2 | 1 | 10 | 8.9 | 500 |
| 9013 | 20180911 | 13:08 | 44º53'98 | 2º27'82 | 18E7 | 44.90 | -2.46 | 39.7 | 0 | 9.6 | 0.0 | |
| 9014 | 20180911 | 18:23 | 45º05'09 | 2º00'03 | 19E7 | 45.08 | -2.00 | 629.5 | 0 | 8.5 | 81.4 | 110 |
| 9015 | 20180912 | 13:07 | 45º21'62 | 1º19'75 | 19E8 | 45.36 | -1.33 | 839.5 | 0 | 23 | 110.4 | 34 |
| 9016 | 20180912 | 17:55 | 45º31'82 | 1º39'70 | 20E8 | 45.53 | -1.66 | 31.3 | 0 | 45 | 44.1 | 59 |
| 9017 | 20180913 | 9:24 | 45º19'47 | 2º09'86 | 19E7 | 45.32 | -2.16 | 933.2 | 0 | 16 | 67.0 | 109 |
| 9018 | 20180913 | 12:59 | 45º09'81 | 2º34'68 | 19E7 | 45.16 | -2.58 | 279.1 | 0 | 90 | 8.5 | 132 |
| 9019 | 20180913 | 14:34 | 45º09'82 | 2º34'87 | 19E7 | 45.16 | -2.58 | 279.1 | 0 | 94.7 | 58.9 | 133 |
| 9020 | 20180914 | 13:50 | 45º21'74 | 2º52'65 | 19E7 | 45.36 | -2.88 | 0.0 | 0 | 11 | 4.9 | 139 |
| 9021 | 20180914 | 20:54 | 45º43'17 | 1º59'43 | 20E8 | 45.72 | -1.99 | 38.0 | 0 | 13.5 | 145.5 | 75 |
| 9022 | 20180915 | 8:59 | 45º49'38 | 2º32'09 | 20E7 | 45.82 | -2.53 | 135.3 | 0 | 101 | 29.2 | 114 |
| 9023 | 20180915 | 14:29 | 45º33'32 | 3º12'17 | 20E6 | 45.56 | -3.20 | 8.5 | 0 | 9.2 | 1.6 | 147 |
| 9024 | 20180918 | 15:28 | 46º33'08 | 3º03'94 | 21E6 | 46.55 | -3.07 | 758.3 | 0 | 17 | 41.2 | 108 |
| 9025 | 20180918 | 17:41 | 46º32'36 | 3º04'46 | 22E6 | 46.54 | -3.07 | 422.2 | 0 | 90 | 26.0 | 115 |
| 9026 | 20180918 | 21:38 | 46º38'33 | 2º51'62 | 22E7 | 46.64 | -2.86 | 681.4 | 1 | 18 | 49.0 | 92 |
| 9027 | 20180919 | 14:39 | 46º27'62 | 3º05'85 | 22E6 | 46.46 | -3.10 | 7.7 | 0 | 15 | 210.0 | 70 |
| 9028 | 20180919 | 17:28 | 46º22'53 | 2º43'65 | 21E7 | 46.38 | -2.73 | 921.7 | 0 | 78 | 217.5 | 91 |
| 9029 | 20180920 | 13:53 | 45º56'37 | 3º46'85 | 20E6 | 45.94 | -3.79 | 639.0 | 0 | 155 | 16.5 | 195 |
| 9030 | 20180924 | 20:49 | 46º25'41 | 4º19'31 | 22E5 | 46.42 | -4.32 | 359.3 | 0 | 53 | 53.4 | 148 |
| 9031 | 20180925 | 13:35 | 46º58'39 | 4º12'69 | 22E5 | 46.97 | -4.21 | 1.0 | 0 | | 0.0 | 126 |
| 9032 | 20180925 | 15:41 | 46º32'36 | 4º02'86 | 22E6 | 46.54 | -4.05 | 37.6 | 0 | 113 | 600.0 | 126 |
| 9033 | 20180925 | 21:34 | 47º18'51 | 3º26'68 | 23E6 | 47.31 | -3.44 | 528.7 | 1 | 12.5 | 400.0 | 85 |
| 9034 | 20180926 | 9:40 | 47º32'15 | 3º39'41 | 24E7 | 47.54 | -3.66 | 1479.1 | 0 | 70 | 500.0 | 77 |
| 9035 | 20180926 | 15:10 | 47º15'01 | 4º17'08 | 23E5 | 47.25 | -4.28 | 170.3 | 0 | 99 | 22.85 | 113 |
| 9036 | 20180926 | 18:48 | 47º36'47 | 4º35'00 | 24E5 | 47.61 | -4.58 | 107.7 | 0 | 123 | 7.55 | 136 |
| 9037 | 20180927 | 10:21 | 47º18'37 | 4º51'76 | 23E5 | 47.31 | -4.86 | 0.0 | 0 | 4 | 0.006 | 126 |
| 9038 | 20180927 | 15:47 | 47º35'49 | 4º13'81 | 24E5 | 47.59 | -4.23 | 25.3 | 0 | 92 | 1500.0 | 134 |
| 9039 | 20180928 | 13:00 | 47º00'22 | 3º26'43 | 23E6 | 47.00 | -3.44 | 1964.9 | 0 | 91.5 | 307.7 | 105 |
| 9201 | 20180902 | 10:56 | 43º34'61 | 2º41'00 | 16E7 | 43.58 | -2.68 | 518.5 | 0 | 11 | 15.0 | 200 |
| 9202 | 20180902 | 17:28 | 44º20'12 | 2º41'00 | 17E7 | 44.34 | -2.68 | 408.8 | 0 | 6 | 22.3 | 1000 |

| ST. | DATE (yyyymmdd) | TIME | LAT (Minutes Hex.) | LONG (Minutes Hex.W) | ICES | LAT (Degrees) | LONG (Degrees) | E_k (m2/ml2) | NIGHT HAUL | FISHING DEPTH (m) | ESTIMATED CATCH (kg) | DEPTH (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9203 | 20180903 | 11:57 | 44º10'92 | 3º02'00 | 17E7 | 44.18 | -3.03 | 613.3 | 0 | 12 | 8.0 | 1000 |
| 9204 | 20180903 | 18:03 | 43º33'36 | 3º02'00 | 16E6 | 43.56 | -3.03 | 3791.5 | 0 | 8 | 350.0 | 150 |
| 9205 | 20180904 | 14:38 | 43º34'62 | 2º00'01 | 16E7 | 43.58 | -2.00 | 711.3 | 0 | 6 | 80.0 | 1000 |
| 9206 | 20180904 | 22:08 | 43º48'09 | 2º21'00 | 16E7 | 43.80 | -2.35 | 380.4 | 1 | 5 | 7.6 | 1000 |
| 9207 | 20180905 | 15:01 | 43º38'42 | 2º41'00 | 16E7 | 43.64 | -2.68 | 384.4 | 0 | 60 | 2.5 | 1000 |
| 9208 | 20180907 | 11:52 | 43º58'79 | 3º22'00 | 16E6 | 43.98 | -3.37 | 716.2 | 0 | 11 | 5.9 | 1000 |
| 9209 | 20180907 | 20:08 | 44º43'83 | 3º22'23 | 18E6 | 44.73 | -3.38 | 131.3 | 0 | 6 | 18.8 | 1000 |
| 9210 | 20180908 | 8:58 | 44º40'83 | 5º26'00 | 18E4 | 44.68 | -5.43 | 776.9 | 0 | 120 | 12.3 | 1000 |
| 9211 | 20180908 | 20:01 | 43º48'32 | 5º26'00 | 16E4 | 43.81 | -5.43 | 1106.9 | 0 | 11 | 400.0 | 160 |
| 9212 | 20180909 | 14:17 | 43º59'22 | 6º49'00 | 16E3 | 43.99 | -6.82 | 1205.9 | 0 | 6 | 12.5 | 400 |
| 9213 | 20180910 | 9:11 | 44º23'82 | 5º47'00 | 17E4 | 44.40 | -5.78 | 1157.3 | 0 | 150 | 8.8 | 1000 |
| 9214 | 20180910 | 14:12 | 43º56'42 | 5º47'00 | 16E4 | 43.94 | -5.78 | 478.3 | 0 | 5 | 59.4 | 1000 |
| 9215 | 20180913 | 14:26 | 43º36'58 | 1º36'00 | 16E8 | 43.61 | -1.60 | 1750.9 | 0 | 5 | 16.0 | 90 |
| 9216 | 20180913 | 20:12 | 43º51'68 | 1º58'23 | 16E8 | 43.86 | -1.98 | 1180.7 | 0 | 9 | 263.5 | 150 |
| 9217 | 20180914 | 13:53 | 44º06'09 | 2º09'00 | 17E7 | 44.10 | -2.15 | 1106.3 | 0 | 7 | 63.5 | 500 |
| 9218 | 20180914 | 20:45 | 44º06'05 | 1º41'00 | 17E8 | 44.10 | -1.68 | 1451.4 | 0 | 6 | 56.0 | 115 |
| 9219 | 20180915 | 10:14 | 44º21'63 | 1º47'00 | 17E8 | 44.36 | -1.78 | 3126.7 | 0 | 6 | 600.0 | 123 |
| 9220 | 20180915 | 14:24 | 44º21'66 | 2º11'50 | 17E7 | 44.36 | -2.19 | 1025.0 | 0 | 150 | 5.5 | 500 |
| 9221 | 20180915 | 20:40 | 44º36'64 | 2º35'50 | 18E7 | 44.61 | -2.59 | 72.5 | 1 | 6 | 90.8 | 500 |
| 9222 | 20180916 | 10:08 | 44º36'66 | 2º03'00 | 18E7 | 44.61 | -2.05 | 950.3 | 0 | 6 | 42.0 | 180 |
| 9223 | 20180916 | 13:58 | 44º36'70 | 2º00'50 | 18E7 | 44.61 | -2.01 | 806.2 | 0 | 140 | 25.0 | 155 |
| 9224 | 20180916 | 19:58 | 44º36'70 | 1º38'50 | 18E8 | 44.61 | -1.64 | 4575.0 | 0 | 1 | 450.0 | 95 |
| 9225 | 20180917 | 9:05 | 45º06'58 | 1º22'00 | 19E8 | 45.11 | -1.37 | 3342.8 | 0 | 22 | 250.0 | 37 |
| 9226 | 20180917 | 15:21 | 44º52'59 | 1º44'00 | 18E8 | 44.88 | -1.73 | 4296.1 | 0 | 7 | 70.0 | 96 |
| 9227 | 20180917 | 19:58 | 44º52'46 | 2º05'50 | 18E7 | 44.87 | -2.09 | 923.5 | 0 | 7 | 130.0 | 150 |
| 9228 | 20180926 | 15:50 | 45º57'39 | 2º12'50 | 20E7 | 45.96 | -2.21 | 1.0 | 0 | 7 | 0.0 | 75 |
| 9229 | 20180926 | 19:52 | 45º54'60 | 2º19'23 | 20E7 | 45.91 | -2.33 | 718.9 | 0 | 7 | 120.0 | 90 |
| 9230 | 20180927 | 12:51 | 46º48'18 | 3º11'50 | 22E6 | 46.80 | -3.19 | 2891.3 | 0 | 79 | 45.0 | 96 |
| 9231 | 20180927 | 20:52 | 46º32'01 | 3º47'00 | 22E6 | 46.53 | -3.78 | 1073.1 | 1 | 7 | 72.0 | 138 |
| 9232 | 20180928 | 9:48 | 46º06'16 | 2º37'23 | 21E7 | 46.10 | -2.63 | 1580.8 | 0 | 87 | 115.0 | 104 |
| 9233 | 20180928 | 13:53 | 46º17'27 | 2º09'50 | 21E7 | 46.29 | -2.16 | 3616.7 | 0 | 13 | 27 | 41 |
| 9234 | 20180928 | 21:10 | 46º07'64 | 1º47'00 | 21E8 | 46.13 | -1.78 | 52.3 | 1 | 6 | 87.5 | 41 |

**Table 4:**
Species composition of the fishing performed by Ramon Margalef (90xx) and Emma Bardán (92xx).

| STATION | BOARDING WEIGHT (kg) | BOARDING WEIGHT/ SPECIES (kg) | *SPECIES* | Fao |
|---|---|---|---|---|
| 9001 | 7.0 | 7.00 | *Engraulis encrasicholus* | ANE |
| 9002 | 3.0 | 0.00 | *Engraulis encrasicholus* | ANE |
| | | 1.19 | *Myctophidae* | LXX |
| | | 0.05 | *Euphasiacea* | KRX |
| | | 1.76 | *Thalia democratica* | SPX |
| 9003 | 5.0 | 4.23 | *Engraulis encrasicholus* | ANE |
| | | 0.18 | *Trachurus trachurus* | HOM |
| | | 0.13 | *Loligo vulgaris* | SQR |
| | | 0.45 | *Thalia democratica* | SPX |
| 9004 | 15.7 | 15.65 | *Engraulis encrasicholus* | ANE |
| 9005 | 60.8 | 60.71 | *Engraulis encrasicholus* | ANE |
| | | 0.07 | *sarda sarda* | BON |
| | | 0.01 | *Rhopilema spp* | JEL |
| 9006 | 11.1 | 11.05 | *Engraulis encrasicholus* | ANE |
| 9007 | 0.5 | 0.00 | *Engraulis encrasicholus* | ANE |
| | | 0.50 | *Myctophidae* | LXX |
| 9008 | 21.8 | 21.72 | *Engraulis encrasicholus* | ANE |
| | | 0.03 | *sarda sarda* | BON |
| 9009 | 1.6 | 0.00 | *Engraulis encrasicholus* | ANE |
| | | 0.11 | *Loligo vulgaris* | SQR |
| | | 0.44 | *Myctophidae* | LXX |
| | | 0.02 | *Euphasiacea* | KRX |
| | | 1.02 | *Thalia democratica* | SPX |
| 9010 | 90.7 | 0.00 | *Engraulis encrasicholus* | ANE |
| | | 2.53 | *Myctophidae* | LXX |
| | | 88.17 | *Euphasiacea* | KRX |
| 9011 | 25.0 | 0.00 | *Engraulis encrasicholus* | ANE |
| | | 3.10 | *Myctophidae* | LXX |
| | | 21.85 | *Euphasiacea* | KRX |
| 9012 | 8.9 | 1.34 | *Engraulis encrasicholus* | ANE |
| | | 3.51 | *Loligo vulgaris* | SQR |
| | | 1.52 | *Myctophidae* | LXX |
| | | 2.53 | *Euphasiacea* | KRX |
| 9013 | 0.0 | 0.00 | *Engraulis encrasicholus* | ANE |
| | | 0.00 | *Trachurus trachurus* | HOM |
| | | 0.03 | *Thalia democratica* | SPX |
| 9014 | 81.4 | 81.40 | *Engraulis encrasicholus* | ANE |
| 9015 | 110.4 | 4.76 | *Engraulis encrasicholus* | ANE |
| | | 37.42 | *Sardina pilchardus* | PIL |

| STATION | BOARDING WEIGHT (kg) | BOARDING WEIGHT/ SPECIES (kg) | *SPECIES* | Fao |
|---|---|---|---|---|
| | | 0.95 | *Trachurus trachurus* | HOM |
| | | 0.40 | *Scomber scombrus* | MAC |
| | | 65.80 | *Sprattus sprattus* | SPR |
| | | 0.14 | *Loligo vulgaris* | SQR |
| **STATION** | **BOARDING WEIGHT (kg)** | **BOARDING WEIGHT/ SPECIES (kg)** | ***SPECIES*** | **Fao** |
| | | 0.88 | *Trisopterus luscus* | BIB |
| 9016 | 44.1 | 34.67 | *Engraulis encrasicholus* | ANE |
| | | 4.51 | *Sardina pilchardus* | PIL |
| | | 0.17 | *Scomber scombrus* | MAC |
| | | 3.29 | *Sprattus sprattus* | SPR |
| | | 1.47 | *Merluccius merluccius* | HKE |
| 9017 | 67.0 | 67.00 | *Engraulis encrasicholus* | ANE |
| 9018 | 8.5 | 0.10 | *Engraulis encrasicholus* | ANE |
| | | 4.25 | *Myctophidae* | LXX |
| | | 4.15 | *Rhopilema spp* | JEL |
| 9019 | 58.9 | 0.00 | *Engraulis encrasicholus* | ANE |
| | | 4.66 | *Loligo vulgaris* | SQR |
| | | 53.31 | *Myctophidae* | LXX |
| | | 0.23 | *Euphasiacea* | KRX |
| | | 0.64 | *Thalia democratica* | SPX |
| 9020 | 4.9 | 4.85 | *Engraulis encrasicholus* | ANE |
| 9021 | 145.5 | 138.29 | *Engraulis encrasicholus* | ANE |
| | | 0.10 | *Sardina pilchardus* | PIL |
| | | 7.03 | *Trachurus trachurus* | HOM |
| | | 0.08 | *Scomber scombrus* | MAC |
| 9022 | 29.2 | 0.11 | *Engraulis encrasicholus* | ANE |
| | | 0.03 | *Trachurus trachurus* | HOM |
| | | 0.00 | *Scomber scombrus* | MAC |
| | | 27.54 | *Sprattus sprattus* | SPR |
| | | 0.21 | *Micromesistius poutassou* | WHB |
| | | 0.03 | *Loligo vulgaris* | SQR |
| | | 1.25 | *Merluccius merluccius* | HKE |
| | | 0.02 | *Myctophidae* | LXX |
| 9023 | 1.6 | 1.60 | *Engraulis encrasicholus* | ANE |
| 9024 | 41.2 | 41.20 | *Engraulis encrasicholus* | ANE |
| 9025 | 26.5 | 2.32 | *Engraulis encrasicholus* | ANE |
| | | 9.19 | *Trachurus trachurus* | HOM |
| | | 0.78 | *Sprattus sprattus* | SPR |
| | | 0.50 | *Micromesistius poutassou* | WHB |
| | | 0.06 | *Loligo vulgaris* | SQR |
| | | 8.24 | *Merluccius merluccius* | HKE |
| | | 5.36 | *Myctophidae* | LXX |
| 9026 | 49.0 | 45.84 | *Engraulis encrasicholus* | ANE |

| STATION | BOARDING WEIGHT (kg) | BOARDING WEIGHT/ SPECIES (kg) | SPECIES | Fao |
|---|---|---|---|---|
| | | 0.44 | *Sardina pilchardus* | PIL |
| | | 0.73 | *Trachurus trachurus* | HOM |
| | | 0.90 | *Scomber scombrus* | MAC |
| | | 1.06 | *Sprattus spratus* | SPR |
| | | 0.02 | *Loligo vulgaris* | SQR |
| | | 0.01 | *Others* | OT |
| 9027 | 210.0 | 210.00 | *Engraulis encrasicholus* | ANE |
| 9028 | 217.5 | 110.04 | *Engraulis encrasicholus* | ANE |
| **STATION** | **BOARDING WEIGHT (kg)** | **BOARDING WEIGHT/ SPECIES (kg)** | ***SPECIES*** | **Fao** |
| | | 31.93 | *Trachurus trachurus* | HOM |
| | | 9.68 | *Scomber scombrus* | MAC |
| | | 10.881 | *Scomber colias* | VMA |
| | | 17.19 | *Sprattus spratus* | SPR |
| | | 0.49 | *Loligo vulgaris* | SQR |
| | | 2.90 | *Merluccius merluccius* | HKE |
| | | 34.39 | *Zeus faber* | JOD |
| 9029 | 16.5 | 0.00 | *Engraulis encrasicholus* | ANE |
| | | 1.60 | *Myctophidae* | LXX |
| | | 14.90 | *Euphasiacea* | KRX |
| 9030 | 53.4 | 0.00 | *Engraulis encrasicholus* | ANE |
| | | 5.32 | *Scomber scombrus* | MAC |
| | | 9.15 | *Micromesistius poutassou* | WHB |
| | | 4.04 | *Loligo vulgaris* | SQR |
| | | 7.02 | *Myctophidae* | LXX |
| | | 27.87 | *Euphasiacea* | KRX |
| 9032 | 600.0 | 598.78 | *Engraulis encrasicholus* | ANE |
| | | 0.09 | *Trachurus trachurus* | HOM |
| | | 0.32 | *Scomber scombrus* | MAC |
| | | 0.81 | *Myctophidae* | LXX |
| 9033 | 400.0 | 356.99 | *Engraulis encrasicholus* | ANE |
| | | 4.21 | *Sardina pilchardus* | PIL |
| | | 1.75 | *Trachurus trachurus* | HOM |
| | | 3.37 | *Scomber scombrus* | MAC |
| | | 33.68 | *Sprattus spratus* | SPR |
| 9034 | 500.0 | 490.13 | *Engraulis encrasicholus* | ANE |
| | | 9.87 | *Sprattus spratus* | SPR |
| 9035 | 22.9 | 16.93 | *Engraulis encrasicholus* | ANE |
| | | 0.63 | *Trachurus trachurus* | HOM |
| | | 1.12 | *Scomber scombrus* | MAC |
| | | 0.25 | *Sprattus spratus* | SPR |
| | | 2.43 | *Merluccius merluccius* | HKE |
| | | 1.49 | *Myctophidae* | LXX |
| 9036 | 7.6 | 1.10 | *Engraulis encrasicholus* | ANE |

| STATION | BOARDING WEIGHT (kg) | BOARDING WEIGHT/ SPECIES (kg) | *SPECIES* | Fao |
|---|---|---|---|---|
| | | 0.23 | *Trachurus trachurus* | HOM |
| | | 0.16 | *Scomber scombrus* | MAC |
| | | 0.18 | *Merluccius merluccius* | HKE |
| | | 0.00 | *Capros aper* | BOC |
| | | 5.87 | *Myctophidae* | LXX |
| | | 0.01 | *Thalia democratica* | SPX |
| 9037 | 0.0 | 0.00 | *Engraulis encrasicholus* | ANE |
| | | 0.01 | *Trachurus trachurus* | HOM |
| | | 0.00 | *Capros aper* | BOC |
| 9038 | 1500.0 | 1500.00 | *Engraulis encrasicholus* | ANE |
| 9039 | 307.7 | 108.48 | *Engraulis encrasicholus* | ANE |
| | | 3.28 | *Trachurus trachurus* | HOM |
| | | 1.87 | *Scomber scombrus* | MAC |
| | | 155.34 | *Sprattus spratus* | SPR |
| | | 37.10 | *Merluccius merluccius* | HKE |
| | | 1.65 | *Myctophidae* | LXX |
| 9201 | 15.0 | 15.00 | *Engraulis encrasicholus* | ANE |
| 9202 | 22.3 | 22.25 | *Engraulis encrasicholus* | ANE |
| 9203 | 8.0 | 8.00 | *Engraulis encrasicholus* | ANE |
| 9204 | 350.0 | 350.00 | *Engraulis encrasicholus* | ANE |
| 9205 | 80.0 | 80.00 | *Engraulis encrasicholus* | ANE |
| 9206 | 7.6 | 7.50 | *Engraulis encrasicholus* | ANE |
| | | 0.08 | *Trachurus trachurus* | HOM |
| | | 0.01 | *Myctophidae* | LXX |
| 9207 | 2.5 | 0.00 | *Engraulis encrasicholus* | ANE |
| | | 2.50 | *Myctophidae* | LXX |
| 9208 | 5.9 | 5.85 | *Engraulis encrasicholus* | ANE |
| 9209 | 18.5 | 18.50 | *Engraulis encrasicholus* | ANE |
| 9210 | 12.3 | 0.00 | *Engraulis encrasicholus* | ANE |
| | | 12.25 | *Myctophidae* | LXX |
| 9211 | 400.0 | 32.59 | *Engraulis encrasicholus* | ANE |
| | | 157.23 | *sarda sarda* | BON |
| | | 210.18 | *Euphasiacea* | KRX |
| 9212 | 12.5 | 12.50 | *Engraulis encrasicholus* | ANE |
| 9213 | 8.8 | 0.00 | *Engraulis encrasicholus* | ANE |
| | | 8.75 | *Myctophidae* | LXX |
| 9214 | 59.4 | 59.40 | *Engraulis encrasicholus* | ANE |
| 9215 | 16.0 | 2.15 | *Engraulis encrasicholus* | ANE |
| | | 11.80 | *sarda sarda* | BON |
| | | 2.05 | *Rhopilema spp* | JEL |
| 9216 | 263.5 | 262.19 | *Engraulis encrasicholus* | ANE |

| | | | | |
|---|---|---|---|---|
| | | 0.66 | *Sardina pilchardus* | PIL |
| | | 0.66 | *Trachurus trachurus* | HOM |
| 9217 | 63.5 | 63.50 | *Engraulis encrasicholus* | ANE |
| 9218 | 56.0 | 53.80 | *Engraulis encrasicholus* | ANE |
| | | 1.60 | *Trachurus trachurus* | HOM |
| | | 0.60 | *Loligo vulgaris* | SQR |
| 9219 | 600.0 | 585.06 | *Engraulis encrasicholus* | ANE |
| | | 14.94 | *Sardina pilchardus* | PIL |
| 9220 | 5.5 | 0.00 | *Engraulis encrasicholus* | ANE |
| | | 5.50 | *Myctophidae* | LXX |
| 9221 | 90.8 | 25.20 | *Engraulis encrasicholus* | ANE |
| | | 0.08 | *Myctophidae* | LXX |
| | | 65.52 | *Euphasiacea* | KRX |
| 9222 | 42.0 | 42.00 | *Engraulis encrasicholus* | ANE |
| 9223 | 25.0 | 0.00 | *Engraulis encrasicholus* | ANE |
| | | 25.00 | *Myctophidae* | LXX |
| 9224 | 450.0 | 450.00 | *Engraulis encrasicholus* | ANE |
| **STATION** | **BOARDING WEIGHT (kg)** | **BOARDING WEIGHT/ SPECIES (kg)** | ***SPECIES*** | **Fao** |
| 9225 | 250.0 | 0.00 | *Engraulis encrasicholus* | ANE |
| | | 250.00 | *Sardina pilchardus* | PIL |
| 9226 | 70.0 | 70.00 | *Engraulis encrasicholus* | ANE |
| 9227 | 130.0 | 130.00 | *Engraulis encrasicholus* | ANE |
| 9229 | 120.0 | 93.00 | *Engraulis encrasicholus* | ANE |
| | | 27.00 | *Sprattus spratus* | SPR |
| 9230 | 45.0 | 21.82 | *Engraulis encrasicholus* | ANE |
| | | 23.18 | *Sprattus spratus* | SPR |
| 9231 | 72.0 | 67.45 | *Engraulis encrasicholus* | ANE |
| | | 4.55 | *Scomber scombrus* | MAC |
| 9232 | 115.0 | 24.19 | *Engraulis encrasicholus* | ANE |
| | | 57.65 | *Trachurus trachurus* | HOM |
| | | 33.16 | *Sprattus spratus* | SPR |
| 9233 | 27.0 | 27.00 | *Engraulis encrasicholus* | ANE |
| 9234 | 87.5 | 31.90 | *Engraulis encrasicholus* | ANE |
| | | 9.72 | *Sardina pilchardus* | PIL |
| | | 45.88 | *Trachurus trachurus* | HOM |

**Table 5:**

Synthesis of the abundance estimation (acoustic index of biomass) for Juvena 2018 by main strata

| | Area (n.m.2) | Mean lenght (cm) | Biomass (t) |
|---|---|---|---|
| **Pure juve** | 19955 | 6.1 | 379,835 |
| **Mixed** | 4535 | 10.7 | 63,807 |
| **Garonne** | 2296 | 10.7 | 46,066 |
| **Total** | **26787** | **6.3** | **489,708** |

**Table 8:**
Synthesis of the abundance estimation (acoustic index of biomass) for the eight years of surveys.

| Year | Area+ (mn2) | Size juveniles (cm) | Biomass juveniles (year y) | Biomass Recruits (year y+1) |
|---|---|---|---|---|
| 2003 | 3,476 | 7.9 | 98,601 | 30,399 |
| 2004 | 1,907 | 10.6 | 2,406 | 4,001 |
| 2005 | 7,790 | 6.7 | 134,131 | 17,643 |
| 2006 | 7,063 | 8.1 | 78,298 | 22,604 |
| 2007 | 5,677 | 5.4 | 13,121 | 9,314 |
| 2008 | 6,895 | 7.5 | 20,879 | 10,262 |
| 2009 | 12,984 | 9.1 | 178,028 | 48,556 |
| 2010 | 21,110 | 8.3 | 599,990 | 114,834 |
| 2011 | 21,063 | 6 | 207,625 | 46,518 |
| 2012 | 14,271 | 6.4 | 142,083 | 39,149 |
| 2013 | 18,189 | 7.4 | 105,271 | 71,963 |
| 2014 | 37,169 | 5.9 | 723,946 | 121,962 |
| 2015 | 21,867 | 6.8 | 462,340 | 57,943 |
| 2016 | 16,933 | 7.3 | 371,563 | 70,423 |
| 2017 | 19,808 | 6.6 | 725,403 | |
| 2018 | 26,787 | 6.3 | 489,708 | |

**Table 9:**

Biomass estimation for the rest of fish species of the small pelagic community assessed during JUVENA.

| Especie | <Sa> | Area | <wieight> | <length> | w_i | SigmaTot | Ni | Bi |
|---|---|---|---|---|---|---|---|---|
| Sardina pilchardus | 1096.22353 | 4595.89284 | 38.43 | 16.75 | 0.09 | 1.1662E-05 | 3,063,051,313.51 | 117,725.45 |
| Sprattu spratus | 743.634725 | 6666.77813 | 3.61059714 | 8.30982004 | 0.08 | 6.2307E-06 | 12,829,928,885.30 | 46,323.70 |
| Trachurus trachurus | 836.119649 | 6366.40392 | 18.8967992 | 12.01809 | 0.02055456 | 7.6275E-06 | 2,310,287,355.18 | 43,657.04 |
| Scomber scombrus | 378.078449 | 6937.36625 | 16.7432743 | 13.8759158 | 0.08680779 | 7.9553E-06 | 682,000,016.28 | 11,418.91 |
| Somber japonicus | 927.189344 | 2837.93684 | 462.937994 | 36.5 | 2.7527E-05 | 6.5816E-06 | 3,642,147.07 | 1,686.09 |
| Micromesistius poutassou | 369.972243 | 3998.7434 | 51.4341403 | 19.7280197 | 9.284E-05 | 4.8435E-06 | 11,991,038.25 | 616.75 |
| Capros aper | 365.144618 | 1770.51109 | 1.00645358 | 3.5 | 1.301E-06 | 4.8243E-06 | 166,485.53 | 0.17 |
| Maurolicus muelleri | 485.219611 | 21765.7718 | 0.2612529 | 3.03880911 | 0.13019738 | 7.2822E-07 | 986,497,283,052.57 | 257,725.28 |

**Table O1**.
Sum of total animals/items observed for each group recorded.

| Group | Number of sightings | Suma de total |
|---|---|---|
| **Seabirds** | 1674 | 5258 |
| **Marine mammals** | 338 | 2540 |
| **Other Marine Wildlife** | 42 | 164 |
| **Landbirds** | 38 | 108 |
| **Marine debris** | 146 | 156 |
| **Human activities** | 222 | 246 |
| **Others** | 12 | 9 |
| **Total general** | 2472 | 8481 |

**Table O2**. List of taxa observed during JUVENA 2018 for seabirds, marine mammals, other marine wildlife, marine debris, human activities and landbirds.

| Group | Common_name | Scientific_name | Number_of_sightings | Group_size | Total_sum |
|---|---|---|---|---|---|
| **Sea Bird** | Gannet | Sula bassana (Morus) | 281 | 1.25 ± 0.64 | 352 |
| **Sea Bird** | Great shearwater | Puffinus gravis | 252 | 4.06 ± 13.42 | 1022 |
| **Sea Bird** | Sooty shearwater | Puffinus griseus | 51 | 1.27 ± 0.67 | 65 |
| **Sea Bird** | Lesser black-backed gull | Larus fuscus | 50 | 3.28 ± 12.26 | 164 |
| **Sea Bird** | Gull sp | Larus sp | 39 | 12.72 ± 34.37 | 496 |
| **Sea Bird** | Skua | Catharacta skua | 35 | 1.09 ± 0.37 | 38 |
| **Sea Bird** | Shearwater sp. | Puffinus spp | 24 | 1.38 ± 0.88 | 33 |
| **Sea Bird** | Sabine's gull | Larus sabini | 23 | 10.87 ± 18.47 | 250 |
| **Sea Bird** | European storm-petrel | Hydrobates pelagicus | 13 | 1.38 ± 0.96 | 18 |
| **Sea Bird** | Yellow-legged gull | Larus michahellis | 13 | 6.31 ± 12.9 | 82 |
| **Sea Bird** | Storm-petrel sp | | 13 | 2.08 ± 2.56 | 27 |
| **Sea Bird** | Balearic shearwater | Puffinus mauretanicus | 9 | 1 ± 0 | 9 |
| **Sea Bird** | Tern sp. | Sterna spp | 8 | 2.12 ± 0.83 | 17 |
| **Sea Bird** | Manx shearwater | Puffinus puffinus | 6 | 1 ± 0 | 6 |
| **Sea Bird** | Great cormorant | Phalacrocorax carbo | 3 | 3.33 ± 2.08 | 10 |
| **Sea Bird** | Small gull sp | Larus sp | 3 | 1.33 ± 0.58 | 4 |
| **Sea Bird** | Great black-backed gull | Larus marinus | 2 | 3 ± 2.83 | 6 |
| **Sea Bird** | Common Tern | Sterna hirundo | 2 | 1.5 ± 0.71 | 3 |
| **Sea Bird** | Parasitic jaeger | Stercorarius parasiticus | 2 | 1 ± 0 | 2 |
| **Sea Bird** | Auk sp | Alcidae sp | 1 | | 3 |
| **Sea Bird** | Northern fulmar | Fulmarus glacialis | 1 | | 1 |
| **Sea Bird** | European herring gull | Larus argentatus | 1 | | 1 |
| **Sea Bird** | Larid sp | Laridae spp | 1 | | 1 |
| **Sea Bird** | Pomarine skua | Stercorarius pomarinus | 1 | | 1 |

| | | | | | |
|---|---|---|---|---|---|
| **Sea Bird** | Sandwich Tern | Sterna sandvicensis | 1 | | 15 |
| **Sea Bird** | Total | | 837 | | 2629 |
| **Marine mammal** | Common dolphin | Delphinus delphis | 90 | 9.86 ± 18.16 | 887 |
| **Marine mammal** | Fin whale | Balaenoptera physalus | 41 | 1.59 ± 0.77 | 65 |
| **Marine mammal** | Balaenopterid sp. | Balaenopteridae sp. | 18 | 1.28 ± 0.57 | 23 |
| **Marine mammal** | Striped dolphin | Stenella coeruleoalba | 10 | 25.6 ± 22.15 | 256 |
| **Marine mammal** | Delphinid sp. | Delphinidae sp. | 8 | 4 ± 1.77 | 32 |
| **Marine mammal** | Striped dolphin / Common dolphin | Stenella coeruleoalba / Delphinus delphis | 1 | 5 ± NA | 5 |
| **Marine mammal** | Cuvier's beaked whale | Ziphius cavirostris | 1 | 2 ± NA | 2 |
| **Marine mammal** | Total | | 169 | | 1270 |
| **Land Bird** | Passerine bird | Passeriformes | 14 | 3.5 ± 4.62 | 49 |
| **Land Bird** | Bird of prey | Falconiformes | 2 | 1 ± 0 | 2 |
| **Land Bird** | European robin | Erithacus rubecula | 1 | 1 ± NA | 1 |
| **Land Bird** | Falcon sp | Falco spp | 1 | 1 ± NA | 1 |
| **Land Bird** | Common Chiffchaff | Phylloscopus collybita | 1 | 1 ± NA | 1 |
| **Land Bird** | Total | | 19 | | 54 |
| **Other Marine Wildlife** | Tuna / Bonito | Thunnus spp. / Sarda spp. | 23 | 6.55 ± 6.82 | 144 |
| **Other Marine Wildlife** | Sunfish | Mola mola | 15 | 1.07 ± 0.26 | 16 |
| **Other Marine Wildlife** | Fish sp | Ostéichiens | 4 | 1 ± 0 | 4 |
| **Marine debris** | Plastic trash | Plastic trash | 52 | 1.1 ± 0.41 | 57 |
| **Marine debris** | Fishing trash (net part, buoy…) | Fishing trash (net part, buoy…) | 9 | 1 ± 0 | 9 |
| **Marine debris** | Trash (plastic, wood, oil) | Trash (plastic, wood, oil) | 9 | 1 ± 0 | 9 |
| **Marine debris** | Unnatural wood | Unnatural wood | 3 | 1 ± 0 | 3 |
| **Marine debris** | Total | | 73 | | 78 |
| **Human activity** | Trawler | Trawler | 33 | 1.15 ± 0.44 | 38 |
| **Human activity** | Fishing buoy, setnet | Fishing buoy, setnet | 27 | 1.07 ± 0.27 | 29 |

| | | | | | |
|---|---|---|---|---|---|
| **Human activity** | Tanker (oil, gaz, chemical) | Tanker (oil, gaz, chemical) | 13 | 1 ± 0 | 13 |
| **Human activity** | Merchant ship (containership, cargo, tanker) | Merchant ship (containership, cargo, tanker) | 10 | 1 ± 0 | 10 |
| **Human activity** | Fishing boat (professional) | Fishing boat (professional) | 8 | 1 ± 0 | 8 |
| **Human activity** | Longliner | Longliner | 6 | 1 ± 0 | 6 |
| **Human activity** | Sailing boat | Sailing boat | 6 | 1.67 ± 1.63 | 10 |
| **Human activity** | Ferry | Ferry | 3 | 1 ± 0 | 3 |
| **Human activity** | Pleasure boat | Pleasure boat | 3 | 1.33 ± 0.58 | 4 |
| **Human activity** | Administrative boat (navy, custom, coast guard) | Administrative boat (navy, custom, coast guard) | 1 | 1 ± NA | 1 |
| **Human activity** | Cruise ship | Cruise ship | 1 | 1 ± NA | 1 |
| **Human activity** | Total | | 111 | | 123 |
| **Other** | Tidal front | Tidal front | 12 | 1 ± 0 | 9 |

# Annex 3.2: Anchovy biomass (Engraulis encrasicolus, L.) applying the DEPM, sardine (Sardina pilchardus) egg abundance and top predators in the Bay of Biscay in 2018

*Please see report on next page.*

Working Document to WGACEGG, 19-23 November 2018, Nantes (France)

**Anchovy biomass (*Engraulis encrasicolus*, L.) applying the DEPM, sardine (*Sardina pilchardus*) egg abundance and top predators in the Bay of Biscay in 2018**

by

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## Abstract

The research survey BIOMAN 2018 for the application of the Daily Egg Production Method (DEPM) in the Bay of Biscay anchovy was conducted in May 2018 from the 7th to the 28th covering the whole spawning area of the specie. Two vessels were utilized: The R/V Ramón Margalef to collect the plankton samples and the pelagic trawler Emma Bardán to collect the adult samples. The total area covered was 116,284Km$^2$ and the spawning area was 75,135Km$^2$ for anchovy and 43,207 Km$^2$ for sardine. During the survey 723 vertical plankton samples were obtained (PairoVET), 1,721 horizontal plankton samples (CUFES) and 41 pelagic trawls were performed, from which 37 contained anchovy and all of them were selected for the analysis. Moreover, 8 extra samples were obtained from the commercial fleet and 2 from Pelgas. In total, there were 47 samples for the adult parameters estimate.

12% of the total anchovy eggs were found in the Cantabrian Coast, it was not possible to find the west limit of the spawning there. The survey arrived until 6º20'W the most west longitude ever reached in the historical series. There were eggs all over the French platform, until 200m depth, up to 47º22'N were the limit was found. There were some anchovy eggs at the limit of the 8abd at 48ºN. The weather conditions during the survey were good in general with a mean Sea Surface Temperature of 15.2ºC and a mean sea surface salinity of 34.41.

Total egg production ($P_{tot}$) for anchovy was calculated as the product of spawning area and daily egg production rate ($P_0$), which was obtained from the exponential decay mortality model fitted as a Generalized Linear Model to the egg daily cohorts.

The adult parameters, sex ratio (*R*), batch fecundity (*F*), spawning frequency (*S*) and weight of mature females ($W_f$), were estimated based on the adult samples obtained during the survey. Consequently, the total Biomass obtained for anchovy resulted in 192,088 t, the highest of the series, with a coefficient of variation of 12%. Total egg abundance of sardine at ICES 8abd without the North part was 4.79 E+12 eggs, lower than last year estimate (6.0 E+12) and the historical mean (5.92 E+12) for that area.

This is the third year were sights were achieved. Marine mammals, seabirds, human activities & debris were recorded by one observer. And the second year were eDNA and microplastics were surveyed, looking for an ecosystem survey approach.

# Introduction

Anchovy (*Engraulis encrasicolus*) is one of the commercial species of high economic importance in the Bay of Biscay. The economy of the Spanish purse seine fleets (primarily from the Basque Country, Cantabria and Galicia) and the French fleet rely on this resource (Uriarte *et al*., 1996 and Arregi *et al*., 2004). To provide proper advice on the fishery management, it is necessary to conduct annually a monitoring of the population. Thanks to it, ICES recommended a limited TAC of 33,000 t for 2018.

Anchovy is a short-lived species; therefore, the evaluation of its biomass should be conducted by direct assessment methods as the Daily Egg Production Method (DEPM) (Barange *et al*, 2009). This consists of estimating the spawning stock biomass (*SSB*) as the ratio between the total daily egg production ($P_{tot}$) and the daily fecundity (*DF*) estimates. In consequence, this method requires a survey to collect anchovy eggs (plankton sampling) for estimating the $P_{tot}$ and to collect anchovy adults (adult sampling) for estimating the *DF*. In the case of anchovy, the SSB is equal to the total biomass (B), since at the survey time, which is at the spawning peak, the whole population is spawning. Since 1987, AZTI (Marine and Food Technological Centre, Basque country, Spain), has conducted annually a specific survey to obtain anchovy biomass indices (Somarakis *et al*., 2004; Motos *et al*., 2005, Santos *et al*, 2010, Santos *et al*,2018). In addition, the anchovy Basque fishery has been continuously monitored. This information has been submitted annually to ICES, to advice on the regulation of this fishery.

The survey for the application of the DEPM to estimate the Bay of Biscay anchovy biomass “BIOMAN” is one of the two surveys which give information about the anchovy population in spring. The other one carried out at the same time in May is the acoustic French survey. The biomass indices provided by the acoustic and DEPM surveys together with the information supplied by “JUVENA” (survey to estimate in autumn the juvenile biomass) and the catches of the fleet are used as input variables for a two-stage biomass model used to assess the Bay of Biscay anchovy population (Ibaibarriaga *et al*., 2008). Since 2014 the assessment of the species is carried out in December of each year, and the advice is from January to December.

Apart from the anchovy biomass estimates this survey gives yearly information on the distribution and abundance of sardine eggs and environmental conditions due to the recollection of different parameters in the area surveyed. Moreover, every three years the DEPM is applied to sardine. And since 2016 an observer sighted marine mammals, seabirds, marine litters and human activities, a neuston net for microplastics was used, water was filtered for eDNA analysis, and the zooplankton was analyzed by size looking over the samples since 1987.

This working document describes the BIOMAN2018 survey for the application of the DEPM for the Bay of Biscay anchovy in 2018. First, the data collection, the estimation of the total egg production and the reproductive parameters are described in detail. Then, the biomass index and the age structure of the population are given; those will be used for the assessment and posterior management of this stock. Finally, the historical trajectory of the population is reviewed.

# Material and Methods

## Survey description

The BIOMAN2018 survey was carried out in May from the 7th to the 28th, at the anchovy spawning peak, covering the whole spawning area of the specie in the Bay of Biscay. During the survey, ichthyoplankton and adult samples were obtained for the estimation of total daily egg production and total daily fecundity respectively for anchovy. The age structure of the population was also estimated. In addition, 30 Neuston net were collected spread all over the area to obtain microplastic debris distribution in the area. Moreover, 59 water samples from the surface (from the water intake of the vessel R. Margalef) and 8 samples with a rosette taking water from 5, 50, 200, 500, 1000m and maximum depth were filtered for eDNA analysis to obtain map distribution of fish, marine mammals, seabirds, sharks, turtles and anisakis. Besides, an observer sighted marine mammals, seabirds, marine litters and human activities. Those results will be compared between them.

The collection of plankton samples was carried out on board R/V Ramón Margalef from the 7th to the 28th of May. The area covered was the southeast of the Bay of Biscay (**Fig. 1**), which corresponds to the main spawning area and spawning season of anchovy. The sampling strategy was adaptive. The survey started from the West (transect 5, at 5º10’W); as there were eggs the survey continued to the west looking for the western limit until 6º20’W but the west limit was not found at the Cantabrian sea. Then the survey continuous covering the Cantabrian Coast eastwards up to Pasajes (transect 25, approx. 1º30’W) (**Fig.1**). Then, the survey continued to the north, to find the Northern limit of the spawning area that was found at 47º22’ºN. When the egg abundances found were relatively high, additional transects separated by 7.5 nm were completed. This occurred from the Adour until Arcachon inside the 100m depth and the area of influence of Gironde. The survey was stopped for 12h the 18th of May, after 11 days of survey to do gas oleo.

The strategy of egg sampling was identical to that used in previous years, i.e. a systematic central sampling scheme with random origin and sampling intensity depending on the egg abundance found (Motos, 1994). Stations were situated at intervals of 3 nmi along 15 nmi apart transects perpendicular to the coast or 7.5 in places of high anchovy egg abundance.

At each station, a vertical plankton haul was performed using a PairoVET net (Pair of Vertical Egg Tow, Smith *et al*., 1985 in Lasker, 1985) with a net mesh size of 150 µm for a total retention of the anchovy and sardine eggs under all likely conditions. The net was lowered to a maximum depth of 100 m or 5 m above the bottom in shallower waters. After allowing 10 seconds at the maximum depth for stabilisation, the net was retrieved to the surface at a speed of 1 m $s^{-1}$. A 45kg depressor was used to allow for correctly deploying the net. "G.O. 2030" flowmeters were used to detect sequential clogging of the net during a series of tows.

Immediately after the haul, the net was washed, and the samples obtained were fixed in formaldehyde 4% buffered with sodium tetra borate in sea water. After six hours of fixing, anchovy, sardine and other eggs species were identified, sorted out and counted on board. Afterwards, in the laboratory, the sorting of the samples was finished, and a percentage of the samples were checked to assess the quality of the sorting made at sea. According to that, a portion of the samples were sorted again to ensure no eggs were left in the sample. In the laboratory, anchovy and sardine eggs were classified into morphological stages (Moser and Alshtrom, 1985).

Sample depth, temperature, salinity and fluorescence profiles were obtained at each sampling station using a CTD RBR-XR420 coupled to the PairoVET. At some points determinate before the survey, water was filtered from the surface to obtain chlorophyll samples to calibrate the fluorescence data.

The Continuous Underway Fish Egg Sampler (CUFES, Checkley *et al*., 1997) was used to record the eggs found at 3m depth with a net mesh size of 350µm. The samples obtained were immediately checked in fresh material under the microscope so that the presence/absence of anchovy and sardine eggs were detected in real time. When anchovy eggs were not found in six consecutive CUFES samples in the oceanic area, transect was abandoned. The CUFES system had a CT to record simultaneously temperature and salinity at 3 m depth, a flowmeter to measure the volume of the filtered water, a fluorimeter and a GPS (Geographical Position System) to provide sampling position and time. All these data were registered at real time using the integrated EDAS (Environmental Data Acquisition System) with custom software. A flowcam macro was used on board, some tests were done to obtain zooplankton abundance data from the samples with this equipment.

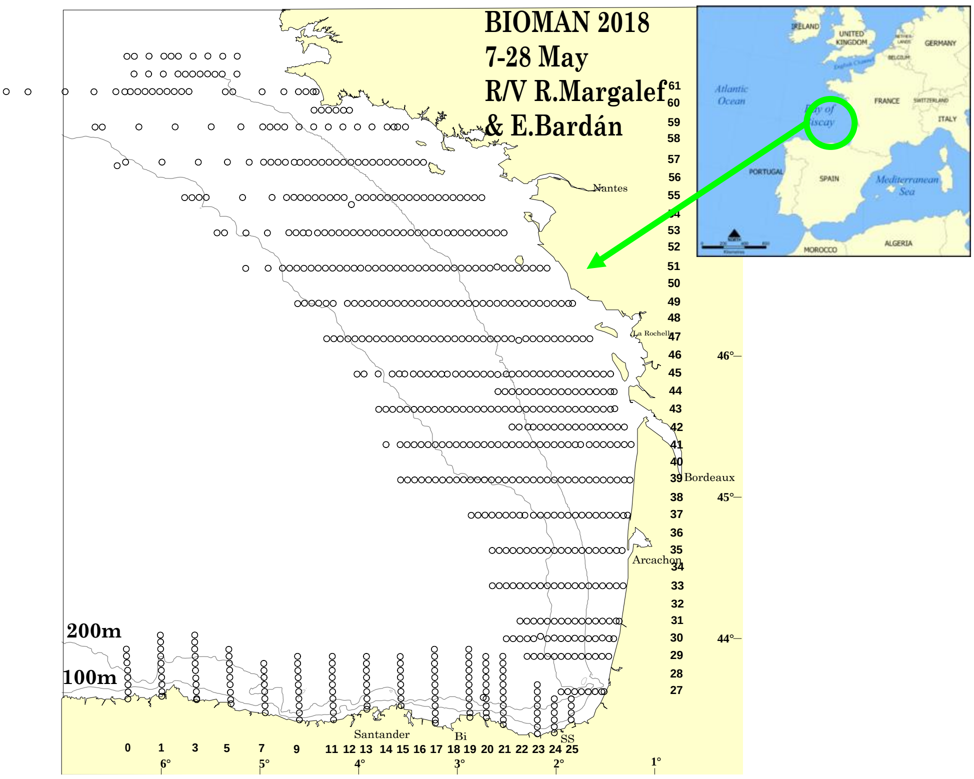


**Figure 1:** Vertical Plankton stations (PairoVET) during BIOMAN 2018.

The adult samples were obtained on board R/V Emma Bardán (pelagic trawler) from the 7th to the 28th of May coinciding in space and time with the plankton sampling. When the plankton vessel encountered areas with anchovy eggs, the R/V Emma Bardán was directed to those areas to fish. In each haul, immediately after fishing, anchovies were sorted from the bulk of the catch and a sample of two kg was selected at random. A minimum of one kg or 60 anchovies were weighted, measured and sexed in each haul. From the mature females, the gonads of 25 non-hydrated females (NHF) were preserved. If the target of 25 NHF was not completed 10 more anchovies were taken at random and processed in the same manner. Sampling was stopped when 120 anchovies had to be sexed to achieve the target of 25 NHF. Otoliths were extracted onboard and read in the laboratory to obtain the age composition per sample. In each haul, 100 individuals (apart from anchovy and sardine) of each species were measured.

## Total egg production

Total daily egg production ($P_{tot}$) was calculated as the product between the spawning area (*SA*) and the daily egg production ($P_0$) estimates:

(1) $$P_{tot} = P_0\ SA.$$

A standard PairoVET sampling station represented a surface of 45 $Nm^2$ (i.e. 154 $km^2$). Since the sampling was adaptive, the area represented by each station was corrected according to the sampling intensity and the cut of the coast. The total area was calculated as the sum of the area represented by each station. The spawning area (*SA*) was delimited with the outer zero anchovy egg stations although it could contain some inner zero anchovy egg stations embedded. The spawning area was computed as the sum of the area represented by the stations within the spawning area.

The daily egg production per area unit ($P_0$) was estimated together with the daily mortality rate (*Z*) from a general exponential decay mortality model of the form:

(2) $$P_{i,j} = P_0 \exp\left(-Z\ a_{i,j}\right),$$

where $P_{i,j}$ and $a_{i,j}$ denote respectively the number of eggs per unit area in cohort *j* in station *i* and their corresponding mean age. Let the density of eggs in cohort *j* in station *i*, $P_{i,j,}$ be the ratio between the number of eggs $N_{i,j}$ and the effective sea area sampled $R_i$ (*i.e.* $P_{i,j} = N_{i,j} / R_i$). The model was written as a generalised linear model (GLM, McCullagh and Nelder, 1989; ICES, 2004) with logarithmic link function:

(3) $$\log\left(E[N_{i,j}]\right) = \log(R_i) + \log\left(P_0\right) - Z\ a_{i,j}\ ,$$

where the number of eggs of daily cohort *j* in station *i* ($N_{ij}$) was assumed to follow a negative binomial distribution. The logarithm of the effective sea surface area sampled ($\log(R_i)$) was an offset accounting for differences in the sea surface area sampled and the logarithm of the daily egg production $\log(P_0)$ and the daily mortality $Z$ rates were the parameters to be estimated.

The eggs collected at sea and sorted into morphological stages had to be transformed into daily cohort frequencies and their mean age calculated to fit the above model. For that purpose, the Bayesian ageing method described in ICES (2004), Stratoudakis *et al*., (2006) and Bernal *et al.*, (2011) was used. This ageing method is based on the probability density function (pdf) of the age of an egg *f(age | stage, temp)*, which is constructed as:

(4) $$f(age \mid stage, temp) \propto f(stage \mid age, temp)\, f(age)\,.$$

The first term *f(stage | age, temp)* is the pdf of stages given age and temperature. It represents the temperature dependent egg development, which is obtained by fitting a multinomial model like extended continuation ratio models (Agresti, 1990) to data from temperature dependent incubation experiments (Ibaibarriaga *et al.,* 2007, Bernal *et al.,* 2008). The second term is the prior distribution of age. A priori the probability of an egg that was sampled at time $\tau$ of having an age *age* is the product of the probability of an egg being spawned at time $\tau$ - *age* and the probability of that egg surviving since then (*exp( -Z age)*):

(5) $$f(age) \propto f(spawn = \tau - age)\, \exp(-Z\ age)\ .$$

The pdf of spawning time *f (spawn=*$\tau$ *- age)* allows refining the ageing process for species with spawning synchronicity that spawn at approximately certain times of the day (Lo, 1985a; Bernal *et al*., 2001). Anchovy spawning time was assumed to be normally distributed with mean at 23:00h GMT and standard deviation of 1.25 (ICES, 2004). The peak of the spawning time was also used to define the age limits for each daily cohort (spawning time peak plus and minus 12 hours). Details on how the number of eggs in each cohort and the corresponding mean age are computed from the pdf of age are given in Bernal *et al.,* 2011. The incubation temperature considered was the one obtained from the CTD at 10m in the way down.

Given that this ageing process depends on the daily mortality rate which is unknown, an iterative algorithm in which the ageing and the model fitting are repeated until convergence of the *Z* estimates was used (Bernal *et al*., 2001; ICES, 2004; Stratoudakis *et al.*, 2006). The procedure is as follows:

Step 1. Assume an initial mortality rate value

Step 2. Using the current estimates of mortality calculate the daily cohort frequencies and their mean age.

Step 3. Fit the GLM and estimate the daily egg production and mortality rates. Update the mortality rate estimate.

Step 4. Repeat steps (1)-(3) until the estimate of mortality converged (i.e. the difference between the old and updated mortality estimates was smaller than 0.0001).

Incomplete cohorts, either because the bulk of spawning for the day was not over at the time of sampling, or because the cohort was so old that its constituent eggs had started to hatch in substantial numbers, were removed to avoid any possible bias. At each station, younger cohorts were dropped if they were sampled before twice the spawning peak width after the spawning peak and older cohorts were dropped if their mean age plus twice the spawning peak width was over the critical age at which less than 99% eggs were expected to be still unhatched. In addition, eggs younger than 4 hours and older than 90% of the survey incubation time (Motos, 1994) were removed.

Once the final model estimates were obtained the coefficient of variation of $P_0$ was given by the standard error of the model intercept ($\log(P_0)$) (Seber, 1982) and the coefficient of variation of Z was obtained directly from the model estimates.

The analysis was conducted in R (www.r-project.org). The ”MASS” library was used for fitting the GLM with negative binomial distribution and the ”egg” library (http://sourceforge.net/projects/ichthyoanalysis/) for the ageing and the iterative algorithm.

## Daily fecundity and total biomass

The daily fecundity (***DF***) is usually estimated as follows:

(6)
$$DF = \frac{R \cdot F \cdot S}{W_f} \; ,$$

where $R$ is the sex ratio in weight, $F$ is the batch fecundity (eggs per batch per female weight), $S$ is the spawning frequency (percentage of females spawning per day) and $W_f$ is the female mean weight.

From 1987 to 1993 the **sex ratio (*R*)** in numbers resulted to be not significantly different from 50%. Therefore, since 1994 the sex ratio in numbers is assumed to be 0.5 and the sex ratio in weight per sample is estimated as the ratio between the average female weight and the sum of the average female and male weights of the anchovies in each of the samples.

A linear regression model between total weight ($W$) and gonad free weight ($W_{gf}$) was fitted to data from non-hydrated females:

(7)
$$E[W] = a + b * W_{gf} \; .$$

This model was used to correct the weight increase of hydrated anchovies. **The female mean weight ($W_f$)** per sample was calculated as the average of the individual female weights.

For **the batch fecundity (*F*)** the hydrated egg method was followed (Hunter and Macewicz., 1985). The number of hydrated oocytes in gonads of a set of hydrated females was counted. This number was deduced from a sub-sampling of the hydrated ovary. Three pieces of approximately 50 mg were removed from the extremes and the centre of one of the ovary lobule of each hydrated anchovy. Those were weighted with precision of 0.1 mg and the number of hydrated oocytes counted. Finally, the number of hydrated oocytes in the sub-sample was raised to the gonad weight of the female according to the ratio between the weights of the gonad and the weight of the sub-samples

The model between the number of hydrated oocytes and the female gonad free weight was fitted as a Generalized Linear Model with Gamma distribution and identity link:

(8) $$E[F] = a + b * W_{gf} \ .$$

The average of the batch fecundity for the females of each sample as derived from the gonad free weight - eggs per batch relationship was then used as the sample estimate of batch fecundity.

Once sex ratio, female mean weight and batch fecundity were estimated per sample, overall mean and variance for each of these parameters were estimated following equations for cluster sampling (Picquelle & Stauffer, 1985):

(9) $$y = \frac{\sum_{i=1}^{n} M_i y_i}{\sum_{i=1}^{n} M_i}$$ and

(10) $$Var(y) = \frac{n \sum_{i=1}^{n} M_i^2 (y_i - y)^2}{\left( \frac{\sum_{i=1}^{n} M_i}{n} \right)^2 n(n-1)} \ ,$$

where *Yi* and *Mi* are the mean of the adult parameter *Y* and the cluster sample size in sample *i* respectively. The variance equation for the batch fecundity was corrected according to Picquelle and Stauffer (1985) in order to account for the additional variance due to model fitting.

The weights *Mi* were taken to reflect the actual size of the catch and to account for the lower reliability when the sample catch was small (Picquelle and Stauffer, 1985). For the estimation of *W* and *F* when the number of mature females per sample was less than 20, the weighting factor was equal to the number of mature females per sample divided by 20; otherwise it was set equal to 1. In the case of R when the total weight of the sample was less than 800 g then the weighting factor was equal to the total weight of the sample divided by 800g, otherwise it was set equal to 1.

The estimation process of the **spawning frequency (*S*)** was estimate following Uriarte *et al.*, 2012.

The Spawning Stock Biomass (*SSB*) that in the case of anchovy is equal to **total biomass (B)** at the spawning peak when the survey occurred, was estimated as the ratio between the total egg production ($P_{tot}$) and daily fecundity (*DF*) estimates and its variance was computed using the Delta method (Seber, *1982*).

## Numbers at age

To deduce the numbers at age different regions were defined depending on the distribution of the adult samples (size, weight and age) and the distribution of anchovy eggs.

Given that mean length and weight of anchovies change between those regions, proportionality between the number of samples and a proxy of the total biomass indices by regions was checked. The approximate index of biomass by regions was set equal to egg abundance divided by the daily fecundity (DF) assigned to each region. The DF by regions was approached by the general formula of this parameter ($F*S*R/W_f$) using the unweight mean of the adult parameters of the samples in the region.

## Predators and human activities

We followed the same methodology implemented in the PELACUS and PELGAS multidisciplinary surveys based on the distance sampling methodology. We performed observations during daylight plankton and acoustic sampling, as well as during certain between-transect navigation while vessel speed and course were constant.

One observer was placed over the bridge of R/V Ramón Margalef, 6 meters high from the sea surface. The observer scanned the water to the front of the boat covering an area of 90º from the trackline to port or starboard (45º to each side), respectively continuously while the vessel was sailing at constant heading and speed during daytime. The temporal observation unit was one minute. The observer recorded the environmental conditions that could affect sightings (i.e., wind speed and direction, sea state, swell height, glare intensity, visibility, etc) and the distance to the sightings and the angle of the sightings with respect to the track-line were estimated. Additional data collected from each sighting included: species, group size, movement direction, behaviour, presence of calves and/or juveniles, etc. All sightings were made with the naked eye while the identifications were supported with 10X42 binoculars.

# Results

## Survey description

This year 12% of the anchovy eggs were found in the Cantabrian Coast. The survey arrived until 6º12'W, the most west longitude ever reached in the historical series but despite this, it was not possible to find the west limit of the spawning. There were eggs all over the French platform, until 200m depth, up to 47º30'N were the limit was found. There were some anchovy eggs at the limit of the 8abd at 48ºN. (**Fig.2**)

The total area covered was 116,284 km² and the spawning area 75,135 km². During the survey 723 vertical plankton samples were obtained, 523 with anchovy eggs (72%) with an average of 550 eggs $m^{-2}$ per station in the positive stations and a maximum of 9,470 eggs $m^{-2}$ in a station. A total of 28,959 anchovy eggs were encountered and classified. 1,721 CUFES samples (horizontal sampling at 3m depth, mesh size net 335) were achieved, 1,148 had anchovy eggs (67%) with an average of 26 eggs $m^{-3}$ per station in the positive stations and a maximum of 466 eggs $m^{-3}$.

An abundance of 7.42 E+12 sardine eggs was encountered in all the area surveyed, 1.5 times higher than last year. To be included in the assessment for sardine in the 8abd the abundance from the cantabric coast and part of the NW was removed, obtaining an egg abundance of 4.79 E+12 eggs. Few eggs were encountered all along the Cantabric coast surveyed. In the French platform the eggs were between coast and 100m depth isoline, all along the coast, from south of France to 47.30ºN, where the north spawning limit was found but there were some eggs encountered at the ICES 8a north limit at 48ºN (**Fig.2**). Part of the eggs were encountered as well between 100 and 200m from 45º30' and 46º30' N. In the plankton samples, from 723 stations, a total of 302 (42%) had sardine eggs with an average of 177 eggs per $m^{-2}$ per station in the positive stations and a maximum of 2,130 eggs $m^{-2}$. in a station and a total number of eggs of 53,480 eggs m². In the sampling with CUFES (horizontal sampling) a total of 620 stations (36%) had sardine from 1,722 stations. To cover the spawning area of sardine in the Bay of Biscay the survey was extended to the North until 48ºN and to the West until the West limit of the sardine spawning area was delimited. But for the propose to be an input for the assessment of sardine in the 8abd, stations from the Northwest were removed to maintain the same coverage of the area of the time series (**Fig.2**).

Both samplers PairoVET (eggm$^{-2}$) and CUFES (eggm$^{-3}$) show very similar anchovy and sardine egg abundances distribution pattern (**Fig.2**).

Distribution maps of anchovy and sardine egg abundances in the last 25 DEPM surveys were compiled (**Fig.24&25**, at the end of the report).

**Figure 3** shows the sea surface temperature and sea surface salinity maps registered during the BIOMAN2018 survey. **Figure 4** shows the SST and SSS maps overlapped with anchovy egg distribution from 20013 to 2017.

This year the mean SST of the survey, 15.2, was higher than last year(14.8ºC), the minimum was 12.1ºC and the maximum17.5ºC. The mean SSS (34.41) was lower than last year (35.12) with a minimum of 31.52 and a maximum of 35.96.

The distribution patterns of sea surface temperature (SST) and sea surface salinity (SSS) observed were the typical for the region at this season showing the signatures of the Adour and Garonne River off the French coast.

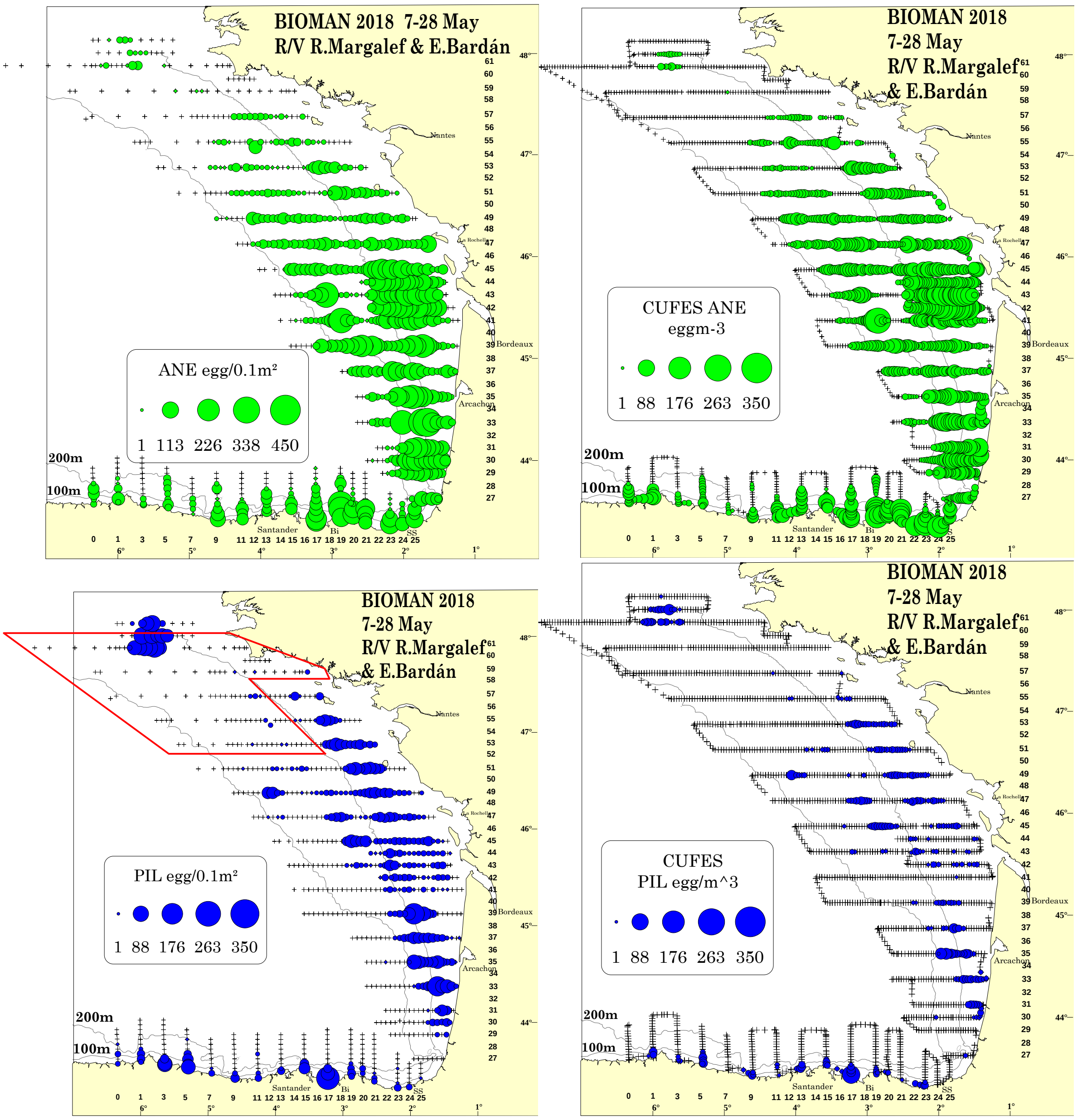


**Figure 2:** Distribution of anchovy (top) and sardine egg abundances (bottom) obtained with PairoVET (left) (eggs per $0.1m^2$) and CUFES (right) (egg per $m^3$) from the DEPM survey BIOMAN2018. The red line delimits the stations removed to maintain the same coverage of the area in the time series for assessment proposes.

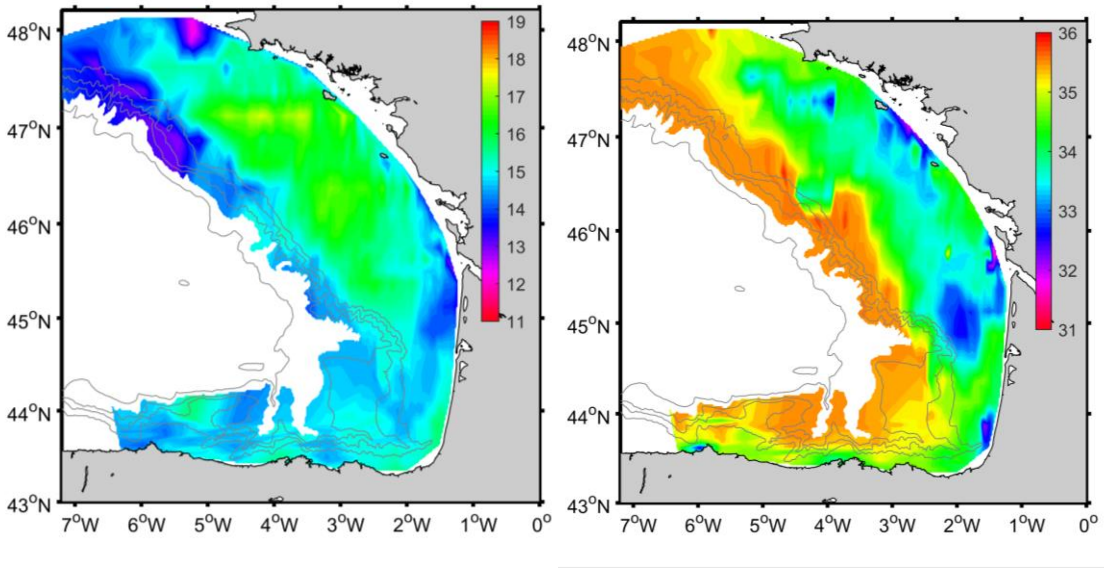


**Figure 3:** SST and SSS maps (left and right respectively) with anchovy egg distribution 2018.

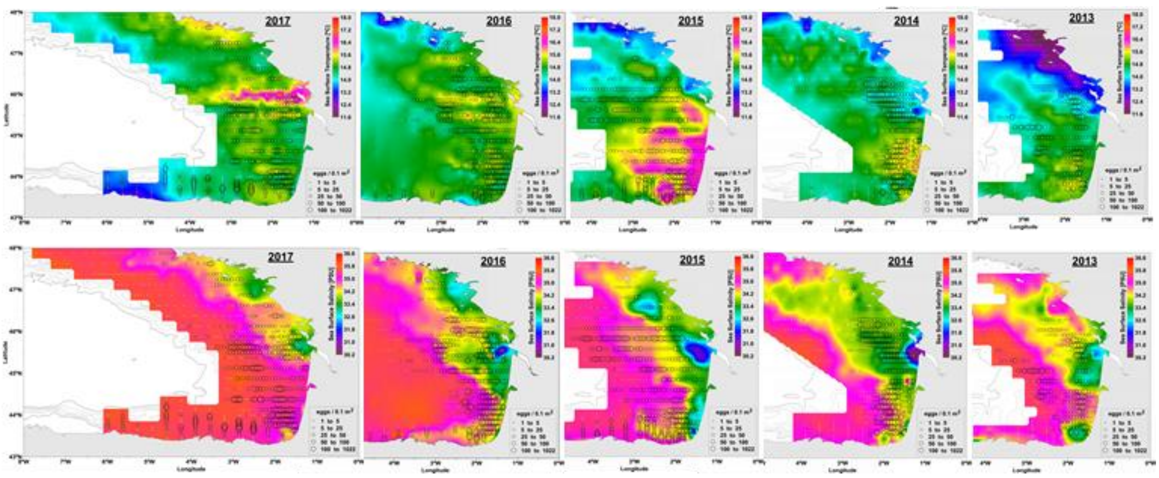


**Figure 4:** SST (top) and SSS (bottom) maps overlapped with anchovy egg distribution from 20013 to 2017.

The adult samples covered adequately the positive spawning area as shown in **Figure 5**. 41 pelagic trawls were performed, from which 37 contained anchovy and all of them were selected for the analysis. This year 8 additional anchovy adult samples were obtained from the Basque purse seine fleet and 2 from the French survey Pelgas on board R/V Thalassa. In total, there were 47 adult anchovy samples to estimate the adult parameters. The spatial distribution of the 47 samples and their species composition is shown in **Figure 5.** The most abundant species in the trawls ware: anchovy, sardine, mackerel and horse mackerel.

Anchovy adults were found in the same places where the anchovy eggs were found.

Spatial distribution of mean weight and mine size for anchovy (males and females) are shown in **Figure 6**. As usually, less weight and less size individuals were found all along the French coast while heavier and bigger anchovies were found offshore in the French platform but this year the biggest anchovy were found in the cantabric coast (**Fig.6**). The mean weight (males and females) 10.9g was the lowest of the historical series as well as the female mean weight 15.29g (**Fig.12**). Since 2010 after the reopen of the fishery, the mean weight of the anchovy population in the Bay of Biscay has been going down gradually.

Anchovy length distribution per haul, in the 5 regions and in the whole area are showed in **figure 7**. These regions were considered to apply weighting factors for the numbers at age estimates.

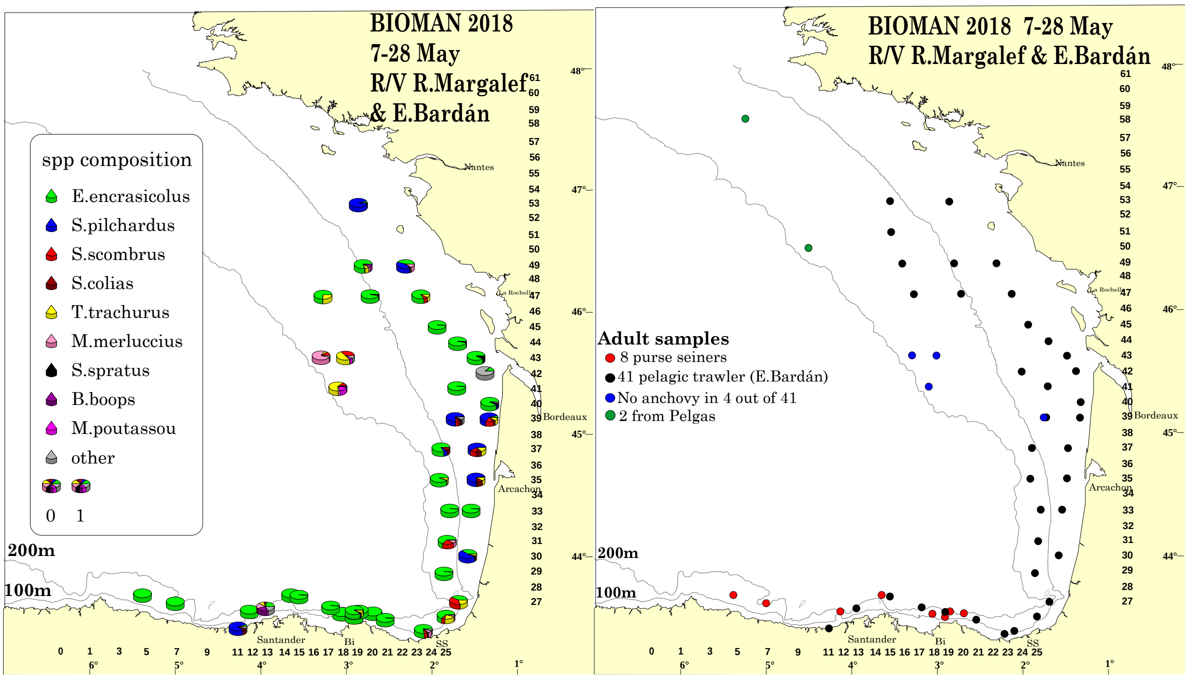


**Figure 5:** On the left the species composition by haul. On the right the spatial distribution of the hauls with anchovy selected for the analysis (47 in total): from pelagic trawlers R/V Emma Bardán (black dots), R/V Thalassa (green) and purse seiners (red) in 2018. The blue ones are the hauls from Emma Bardán that had no anchovy.

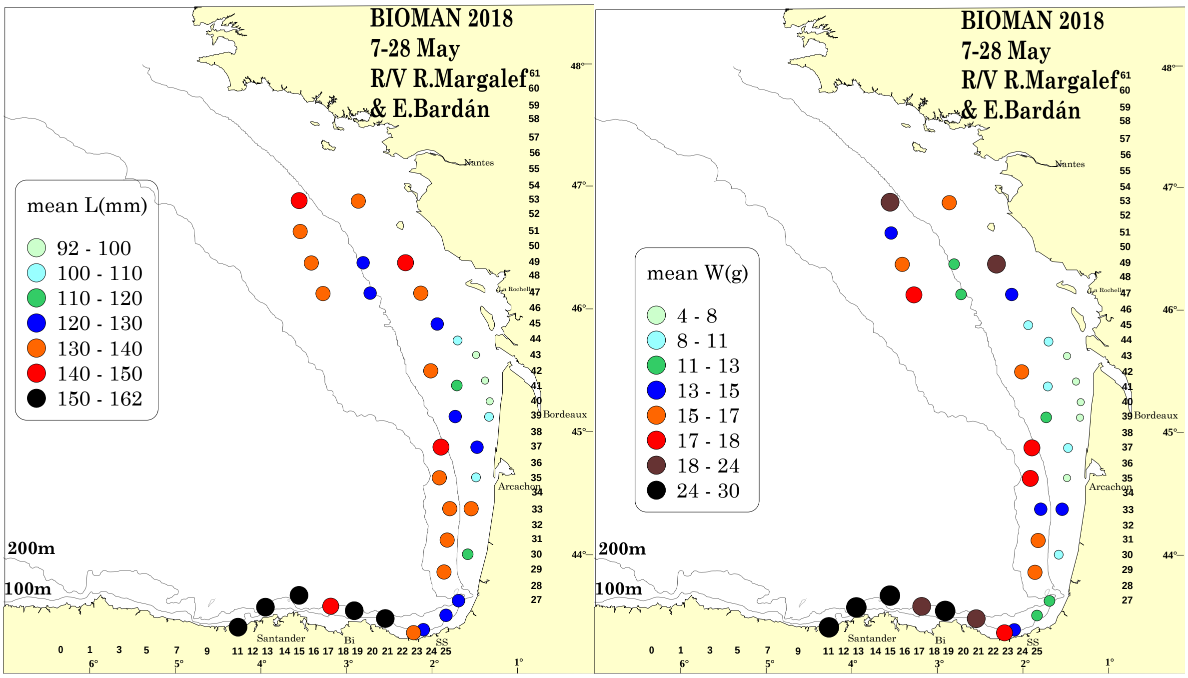


**Figure 6:** Anchovy (male and female) mean size (left) and mean weight (right) in 2018

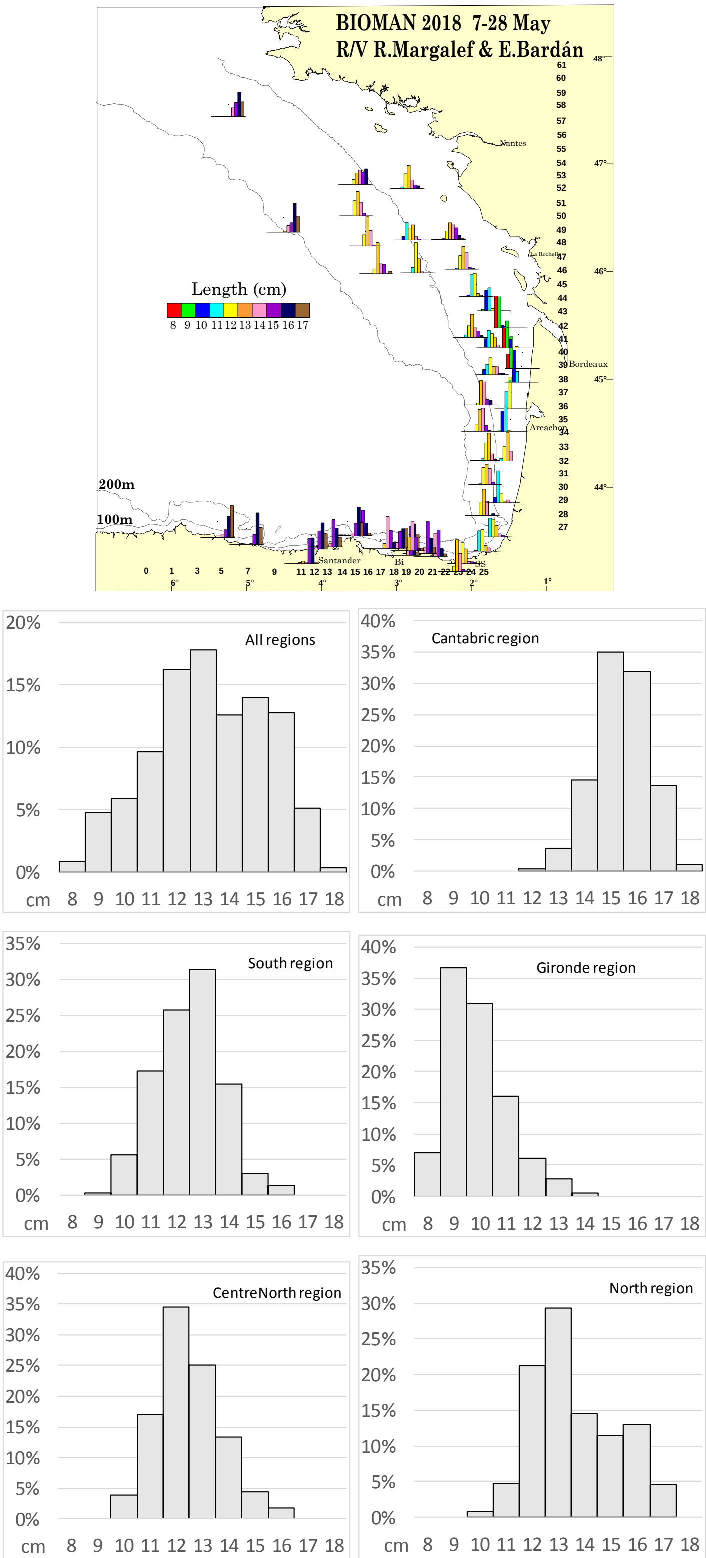


**Figure 7:** Anchovy (male and female) length distribution by haul, by 5 regions and by all the region. Regions considered to apply weighting factors for the numbers at age estimates.

## Total daily egg production estimates

As a result of the adjusted GLM (**Fig.8**) the daily egg production ($P_0$) was 209.36 egg $m^{-2}$ day $^{-1}$ with a standard error of 18.78 and a CV of 0.09, higher than last year and at levels of the highest of the series in 2016 (**Fig.9**). The daily mortality (z) was 0.26 with a standard error of 0.046 and a CV of 0.17 at levels of the historical mean **(Fig.9)**. Then, the total daily egg production ($P_{tot}$) as the product of spawning area and daily egg production was 1.57E+13 with a standard error of 1.4E+12 and a CV of 0.09, been the highest of the historical series (**Fig.9**)

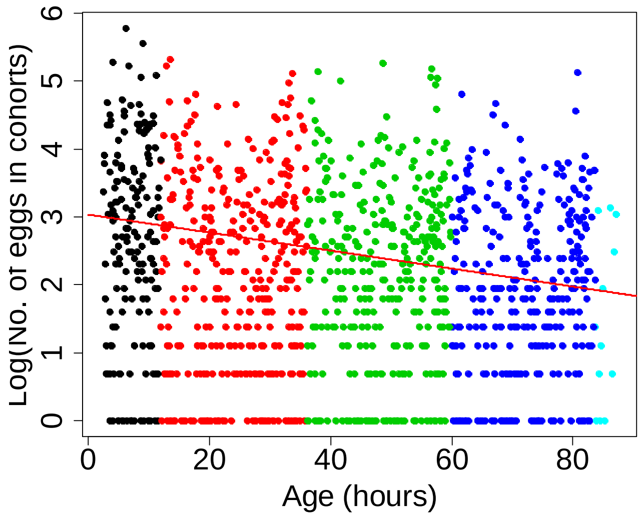


**Figure 8:** Exponential mortality model adjusted applying a GLM to the data obtained in the ageing, following the Bayesian method (spawning peak 23:00h). The red line is the adjusted line. Data in Log scale. The different colours of the bubbles represent the different cohorts.

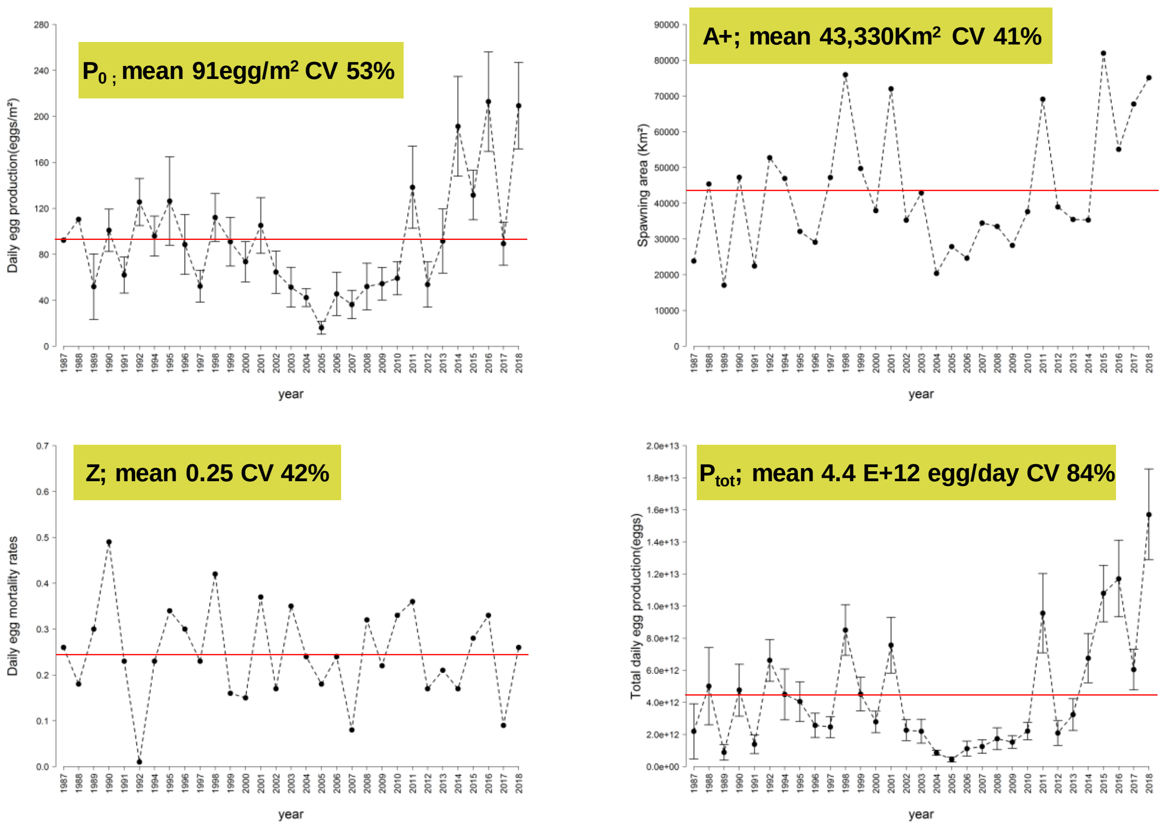


**Figure 9:** Time series of DEPM egg parameters and spawning area for anchovy: daily egg production (egg m-2 per day) ($P_0$), spawning area (Km²) (A+), daily egg mortality rates (z), total daily egg production (eggday-1) ($P_{tot}$). Vertical lines indicate 95% confidence intervals (i.e. ± 2 standard deviations).

## Adult parameters, daily fecundity and total biomass

**Female mean weight ($W_f$)**: The results of the adjusted linear regression model between gonad-free-weight and total weight fitted to non-hydrated females (hydrated females identified macroscopically as stages 3 and 5 based on the maturity scale from WKSPMAT, 2008) for the correction due to hydration of the females are given in **Table 1**. The extra females, not randomly taken, for the estimation of the batch fecundity, were not considered. This correction was done in June and was not modified for the final estimate in November, because it was considered that the females with a hydrated appearance, even though they have POFs, must remain with the correction. The model fitted the data adequately (**Fig.10**, $R^2$=99.7%, n= 832). The female mean weight ($W_f$) of the population, 15.29g CV 0.1007, was obtained as the weighted mean of the average female weights per sample (Lasker, 1985). This year was the lowest of the historical series. Since 2010 after the reopen of the fishery, the anchovy female mean weight in the Bay of Biscay has been going down gradually (**Fig.12**)

**Table 1**: Coefficients resulted from the linear regression model between gonad-free-weight and total weight fitted to non-hydrated females with their standard error and the P-Value.

| Parameter | Estimate | Standard error | P-Value |
|---|---|---|---|
| Intercept | -0.1193 | 0.0310 | 0.0001 |
| Slope | 1.0896 | 0.0020 | 0.0000 |

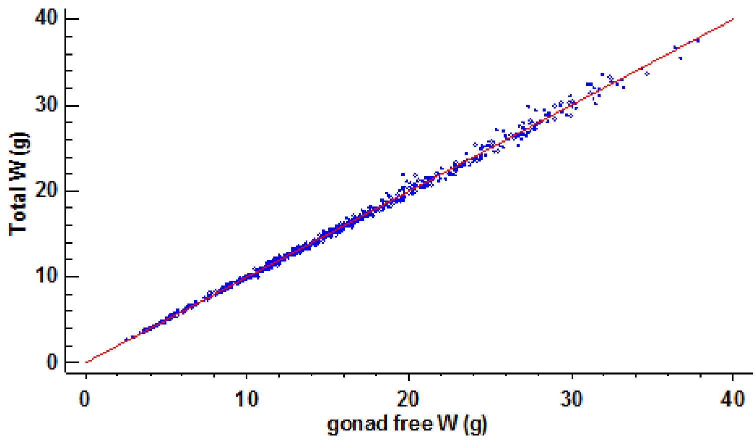


**Figure 10:** linear regression model between gonad-free-weight and total weight fitted to non-hydrated females.

For the **batch fecundity (*F*)** 87 hydrated females from 23 samples, ranging from 2.6 to 41.2 g gonad free weight were examined. It was tested whether the model coefficients changed between the 5 regions considered for the numbers at age (**Fig.13**). Finally, two regions were considered: the Gironde region and the remainder region, instead the 5 regions, due to the inexistent difference between those 5. Statistically significant differences among the two regions at the 95% confidence level were found and were considered to estimate the batch fecundity of all the samples considered for the analysis. The coefficients of the generalised linear model with Gamma distribution and identity link are given in

**Table 2** and the fitted model is shown in **Figure 11**. Hence, the overall batch fecundity estimate (7,119 egg/batch per average mature female CV 0.1007) was obtained as a weighted mean of the batch fecundity per sample (Lasker, 1985). In relation with the historical series is higher than de last 3 years but lower in relation with the historical mean (10,723 eggs per gram per mature female CV 0.2957). the tendency of the batch fecundity has been going down since 2010 (**Fig.12**).

**Table 2:** Coefficients of the generalised linear model with Gamma distribution and identity link between the number of hydrated oocytes and the female gonad free weight ($W_{gf}$) for the Gironde and the remainder area

| Parameter | estimate | Standard error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| Intercept | 985.47 | 332.24 | 2.966 | 0.00394** |
| wgf | 79.96 | 64.37 | 1.242 | 0.21766 |
| remainder | -4363.6 | 741 | -5.889 | 7.99e-08*** |
| wgf:remaind | 660.36 | 84.46 | 7.819 | 1.49e-11*** |

Signif. codes : 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 ***

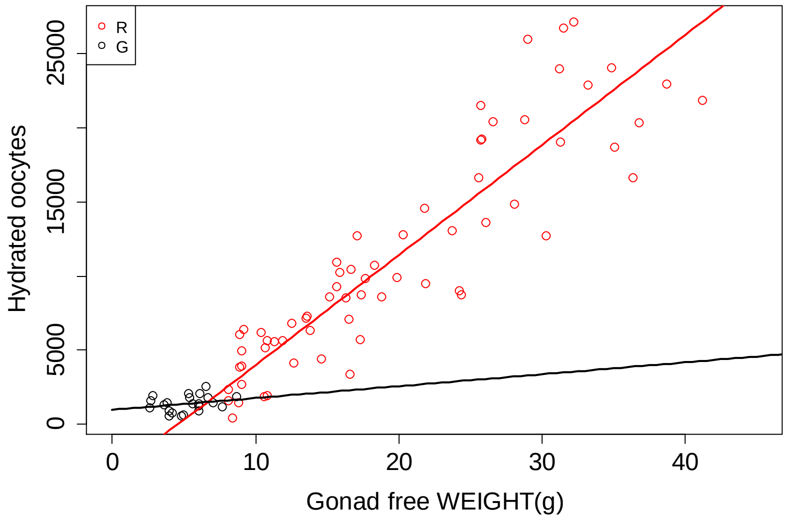


**Figure 11:** Generalised linear model between gonad-free-weight and hydrated oocytes fitted to hydrate females. The black circles are the ones from the Gironde and red are the ones from the rest of the area. The black line is the fit to the Gironde females and the red one the fit to the females from the remainder region.

For the **spawning frequency (*S*)** the estimate was calculated as describe above in material and methods. After the histological analysis of the gonads was completed, using the new staging (Alday *et al.*, 2010) and new ageing (Uriarte *et al.*, 2012), the estimate of S obtained was 0.33 CV 0.0463. In relation with the historical series is at the same levels since 2010 but is lower than the historical mean (38%) **(Fig.12)**.

In June (WGHANSA) a mean of the last 8 years was considered for the **Daily Fecundity (*DF*)** (70 CV 0.11), in November for WGACEGG a *DF* of 82.5 CV 0.0742 was estimated, from the parameters obtained through the adult samples from the survey, presented above. In relation with the historical series it was higher than last year (64.2 eggs/g), actually, higher than the last 8 years but lower than the mean (92.7eggs/g) (**Fig.12**)

Estimates of all the parameter to obtain the biomass through the DEPM and the total biomass with their CVs are given in **table 3**. The anchovy total biomass estimate obtained was 192,088t with a CV of 0.1164 the highest of the historical series (**Fig.12**)

**Table 3:** All the parameters to estimate de total Biomass using the Daily Egg Production Method (DEPM) for 2018: $P_{tot}$ (total egg production), R (sex ratio), S (Spawning frequency), F (batch fecundity), $W_f$ (female mean weight) and DF (daily fecundity) with correspondent Standard errors (S.e.) and coefficients of variation (CV).

| Parameter | estimate | S.e. | CV |
|---|---|---|---|
| Ptot | 1.57E+13 | 1.41E+12 | 0.0897 |
| R' | 0.53 | 0.0048 | 0.0091 |
| S | 0.33 | 0.0153 | 0.0463 |
| F | 7,119 | 717 | 0.1007 |
| Wf | 15.29 | 0.98 | 0.0638 |
| DF | 82.46 | 6.12 | 0.0742 |
| Biomass (Tons) | **192,088** | 22,361 | 0.1164 |

## Numbers at age

To estimate the population at age, the age readings of 2,341 otoliths from 47 samples were available.

To deduce the numbers at age 5 regions were defined depending on the distribution of the adult samples (size, weight and age) and anchovy eggs (**Fig.13**): CA (Cantabric), S (South), G(Gironde), CN (Central North) and N(North). Given that mean length of anchovies change between those regions (**Fig. 7**), proportionality between the number of samples and a proxy of the total biomass indices by regions was checked. The approximate index of biomass by regions was set equal to egg abundance divided by the daily fecundity (*DF*) assigned to each region (**Tab.4**). The *DF* by regions was approached by the general formula of this parameter ($F*S*R/W_f$) using the unweight mean of the adult parameters of the samples in each region.

According to **table 4**, the 47 samples selected are not balanced between those regions and differential weighting factors were applied to each sample coming from one or the other region to estimate the number at age and biomass. The proportion by age, numbers by age, weight by age and biomass by age, length and weight by age estimates are given in **Table 5**. 87% of the population in numbers and 76% in mass correspond to age 1. **Figure 14** shows the distribution of anchovy age composition in space.

The historical series of numbers at age in numbers is shown in **figure 15.** This is a good recruitment year and is the highest of the historical series.

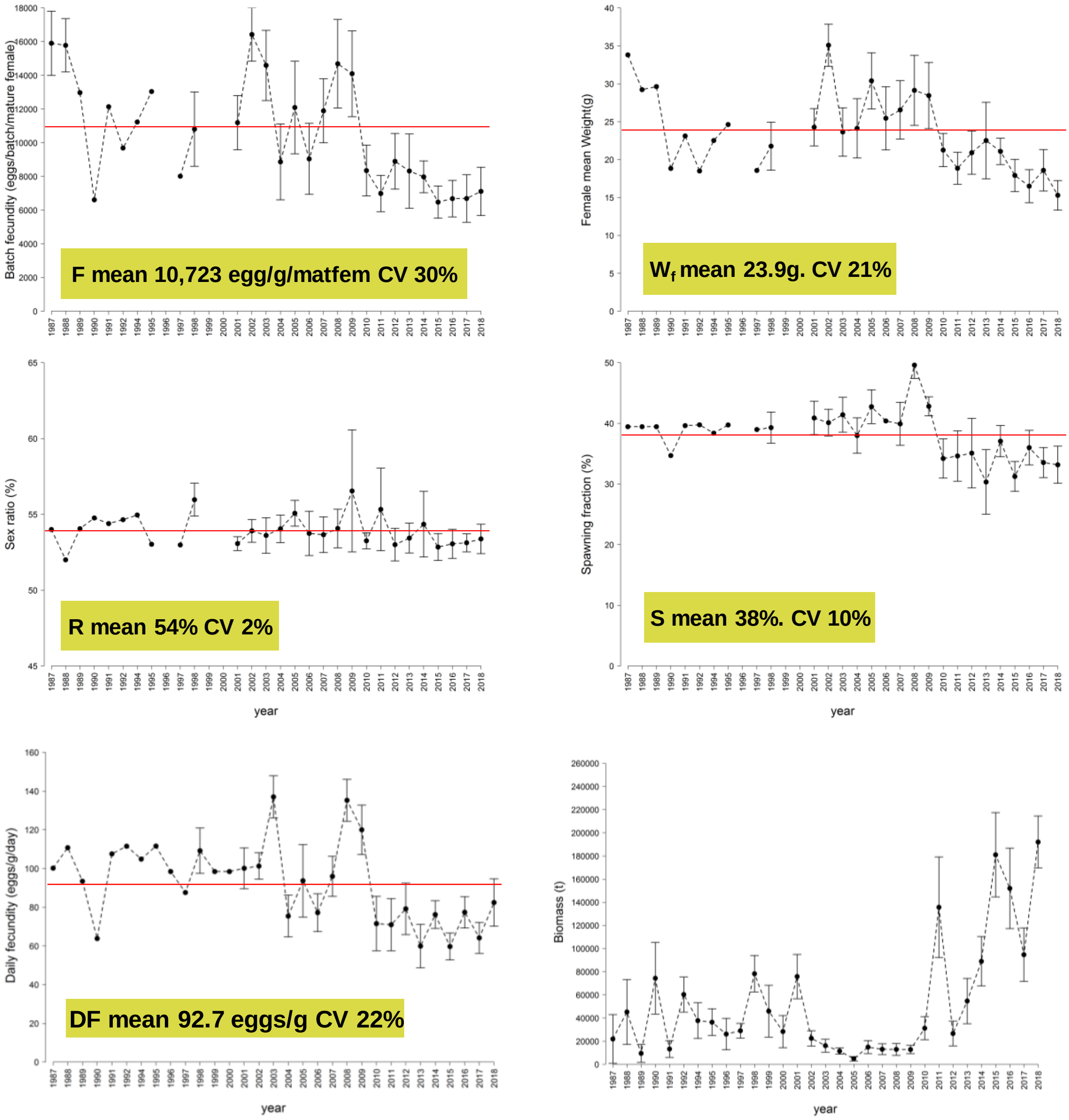


**Figure 12:** Time series of anchovy DEPM adult parameters and total biomass: Batch fecundity (eggs spawned per mature females per batch), female mean weight (g), sex ratio (mature female fraction of population by weight), spawning fraction (fraction of mature females spawning per day), daily fecundity (nº of egg per g of biomass) and total biomass (tons). Vertical lines indicate 95% confidence intervals (i.e. ± 2 standard deviations).

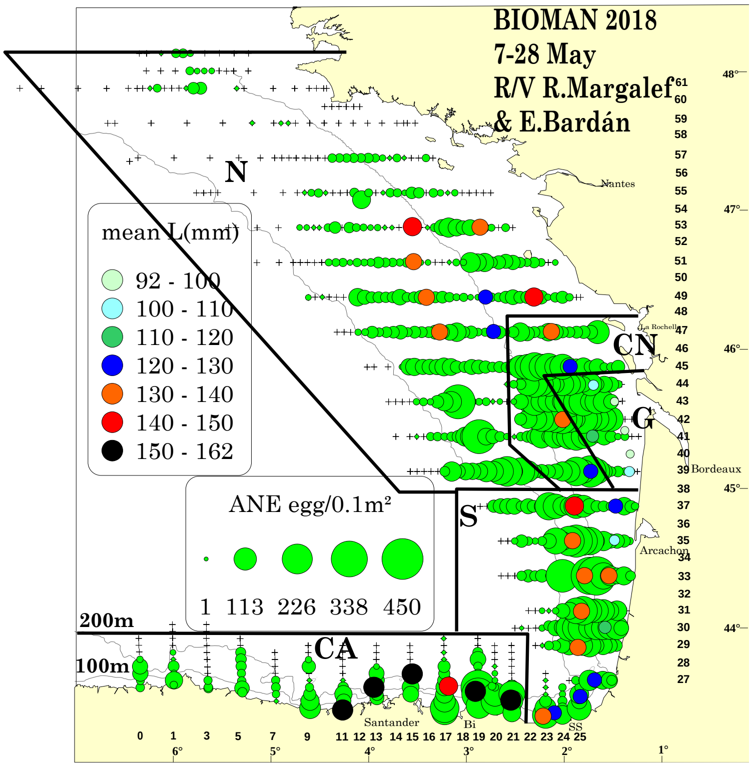


**Figure 13:** 5 regions defined to estimate the numbers at age. The black lines represent the border of the regions, the green bubbles the abundance of anchovy eggs (egg/0.1m$^2$) in each station and the small colour bubbles represent the mean size (mm) of individuals within each haul.

**Table 4:** Balance of adult sampling to egg abundance by 5 regions: Cantabric (C), South (S), Gironde (G), Centre-North (CN) and North (N) in the Bay of Biscay (see **Figure 13**). The 8$^{th}$ row of the table corresponds to the weighting factor for each sample by region to obtain the population structure. Mean weight by regions arise from the 47 adult samples selected for the analysis.

| **Region** | C | S | G | CN | N | Addition |
|---|---|---|---|---|---|---|
| Total egg abundance | 4.5E+12 | 1.4E+13 | 2.7E+12 | 6.4E+12 | 8.2E+12 | 3.6E+13 |
| % egg abundance | 12% | 40% | 7% | 18% | 23% | 100% |
| **DF** | 127 | 73 | 35 | 81 | 110 | |
| **Proxy of B** | 4E+10 | 2E+11 | 7.508E+10 | 7.8E+10 | 7.4E+10 | 4.6E+11 |
| **%Proxy Biomass** | 8% | 43% | 16% | 17% | 16% | 100% |
| Nº of adult samples | 14 | 12 | 6 | 4 | 10 | 46 |
| % proxy Biomass/ nº sample | 0.005 | 0.036 | 0.027 | 0.043 | 0.016 | |
| % of Biomass relative to CN region | 0.13 | 0.83 | 0.64 | 1.00 | 0.38 | |
| W factor proportional to the populat. | 0.13/wi | 0.83/wi | 0.64/wi | 1/wi | 0.38/wi | |
| Mean W of ANE by region | 27.3 | 13.6 | 6.2 | 13.2 | 18.5 | |
| Standard Deviation | 3.3 | 3.2 | 2.6 | 2.5 | 6.9 | |
| CV | 12.2% | 23.8% | 42.0% | 18.9% | 37.1% | |

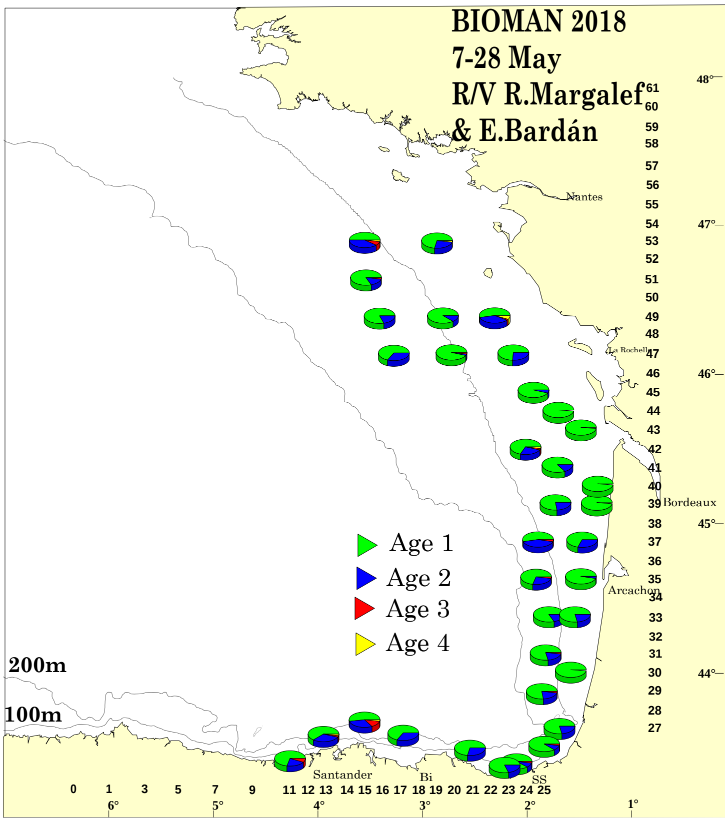


**Figure 14**: Anchovy age composition in space per haul 2018

**Table 5:** 2018 anchovy biomass estimates, total mean weight, population in millions and the percentage, numbers, percentage in mass and biomass at age estimates with correspondent standard error (S.e.) and coefficient of variation (CV). And weight and length at age with correspondent standard error (S.e.) and coefficient of variation (CV).

| Parameter | estimate | S.e. | CV |
|---|---|---|---|
| Biomass (Tons) | **192,088** | 22,361 | 0.1164 |
| Total mean Weight (g) | 10.979 | 1.07 | 0.0974 |
| Population (millions) | 17,530 | 2977 | 0.1699 |
| Percentage at age 1 | 0.8681 | 0.027 | 0.0314 |
| Percentage at age 2 | 0.1241 | 0.025 | 0.2026 |
| Percentage at age 3+ | 0.0077 | 0.002 | 0.2645 |
| Numbers at age 1 | 15,230 | 2,949.0 | 0.1936 |
| Numbers at age 2 | 2,164 | 310.7 | 0.1436 |
| Numbers at age 3+ | 135 | 29.9 | 0.2207 |
| Percent. at age 1 in mass | 0.7553 | 0.033 | 0.0441 |
| Percent. at age 2 in mass | 0.2267 | 0.030 | 0.1345 |
| Percent. at age 3+ in mass | 0.0180 | 0.004 | 0.2197 |
| Biomass at age 1 (Tons) | 145,159 | 19,829 | 0.1366 |
| Biomass at age 2 (Tons) | 43,465 | 6,449 | 0.1484 |
| Biomass at age 3+ (Tons) | 3,463 | 782 | 0.2259 |
| Weight at age 1 (g) | 9.6 | 0.96 | 0.0999 |
| Weight at age 2 (g) | 20.1 | 0.89 | 0.0444 |
| Weight at age 3 (g) | 24.1 | 1.92 | 0.0799 |
| Lenght at age 1 (mm) | 115.1 | 3.55 | 0.0309 |
| Lenght at age 2 (mm) | 145.1 | 1.59 | 0.0110 |
| Length at age 3 (mm) | 149.8 | 4.82 | 0.0322 |

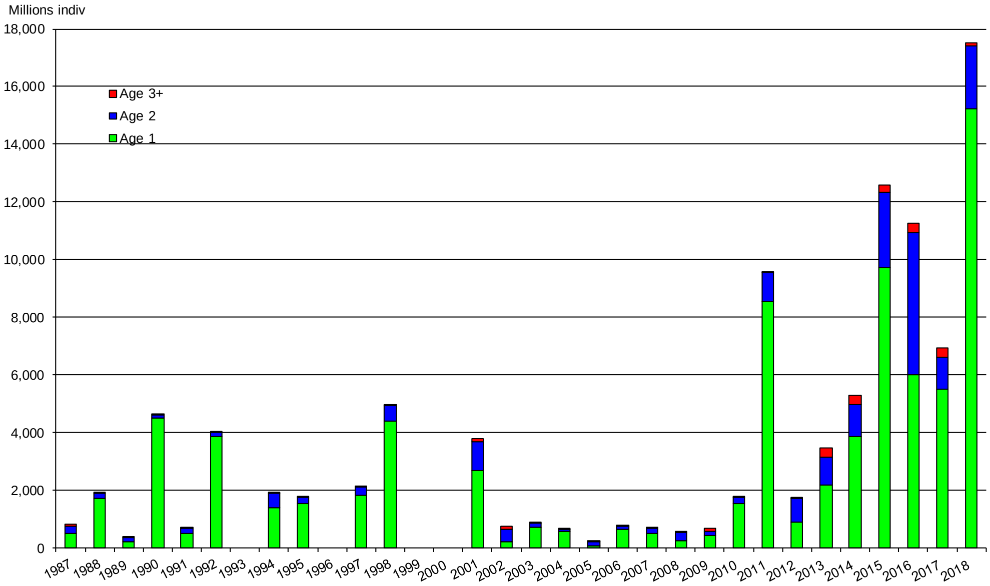


**Figure 15:** Historical series of numbers at age from 1987 to 2018

# Sardine total egg abundance

Total egg abundance for sardine was estimate as the sum of the numbers of eggs in each station multiply by the area each station represents. This year sardine egg abundance estimate was 7.4 E+12 eggs, considering the whole area surveyed. Taking into account the 8abd, the estimate was 6.3 E+12 and removing part of the North for assessment propose, the total egg abundance was 4.8 E+12 eggs below the time series average (5.92E+12) and lower than last year (**Fig.16, Tab.6**). Sardine eggs were encountered all along the Cantabric coast, close to the coast, between 2º and 6º20'W. In the French platform sardine eggs were encountered all along the coast between coast and 100m depth until 47º22'ºN. From Arcachon to the North limit the eggs were not encountered close to the coast. (**Fig.2**). In the sampling with the PairoVET net (vertical sampling) from 723 stations a total of 302 (42%) had sardine eggs with an average of 177 eggs per m² per station in the positive stations, a maximum of 2,130 in a station and a total number of eggs of 53,480 eggs m². In the sampling with CUFES (horizontal sampling) a total of 620 stations (36%) had sardine from 1,722 stations. To cover the spawning area of sardine in the Bay of Biscay the survey was extended to the North until 48ºN and to the West until the West limit of the sardine spawning area was delimited. But for the propose to be an input for the assessment of sardine in the ICES8abd, stations from the Northwest were removed to maintain the same coverage of the area of the time series (**Fig.2**). This egg abundance series was incorporated as an input in the assessment of sardine in the ICES 8abd in June at (WGHANSA).

The historical series of egg abundances is shown in **figure 16** and **table 6**. The sardine egg distribution is shown in **figure 2**.

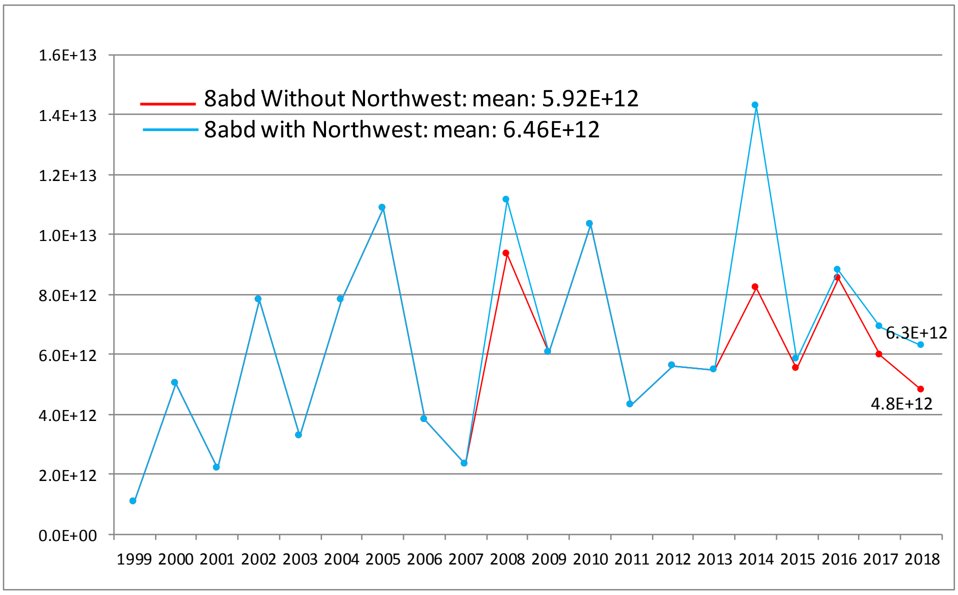


**Figure 16:** historical series of sardine egg abundances 1999-2018 in ICES 8abd, with and without the eggs from part of the Northwest area.

**Table 6:** historical series of sardine egg abundances within 8abd (without eggs from the cantabric coast and part of the North)

| Year | TotAb_8abd_without N |
|---|---|
| 1999 | 1.06E+12 |
| 2000 | 5.03E+12 |
| 2001 | 2.20E+12 |
| 2002 | 7.82E+12 |
| 2003 | 3.26E+12 |
| 2004 | 7.83E+12 |
| 2005 | 1.09E+13 |
| 2006 | 3.84E+12 |
| 2007 | 2.33E+12 |
| 2008 | 9.37E+12 |
| 2009 | 6.05E+12 |
| 2010 | 1.03E+13 |
| 2011 | 4.29E+12 |
| 2012 | 5.60E+12 |
| 2013 | 5.47E+12 |
| 2014 | 8.21E+12 |
| 2015 | 5.52E+12 |
| 2016 | 8.56E+12 |
| 2017 | 5.99E+12 |
| 2018 | 4.79E+12 |
| Mean | **5.92.E+12** |
| Std Dev | **3.E+12** |
| CV | **46.2%** |

## Predators and human activities 2018

308 observations periods (legs) were performed, travelling 1,849 km. A total of 1,325 seabirds, 288 cetaceans, 13 other marine wildlife, 90 marine debris, 132 of human activities and 37 of landbirds were recorded. A complete list is given in **table 7** at the end of the report.

Regarding **marine mammals**, 5 different species were observed. The spatial distribution of the most abundant species is showed in **Figure 17**. The most abundant species was the common dolphin with 26 sightings (group size = 6.69 ± 6.03, a total of 174 individuals), followed by the long-finned pilot whale with 7 sightings (group size = 6.86 ± 4.67, a total of 48 individuals) and the stripped dolphin with 3 sightings (group size = 20.67 ± 21.13, a total of 62 individuals). 2 fin whales and 1 bottlenose dolphins were observed as well. Common dolphins were scattered throughout the study area, in contrast to striped dolphins and long-finned pilot whales that were mainly present over the oceanic areas of the SE corner of the Bay of Biscay and over the submarine canyons of the study area (**Fig.17**). (**Table 7** at the end of the report).

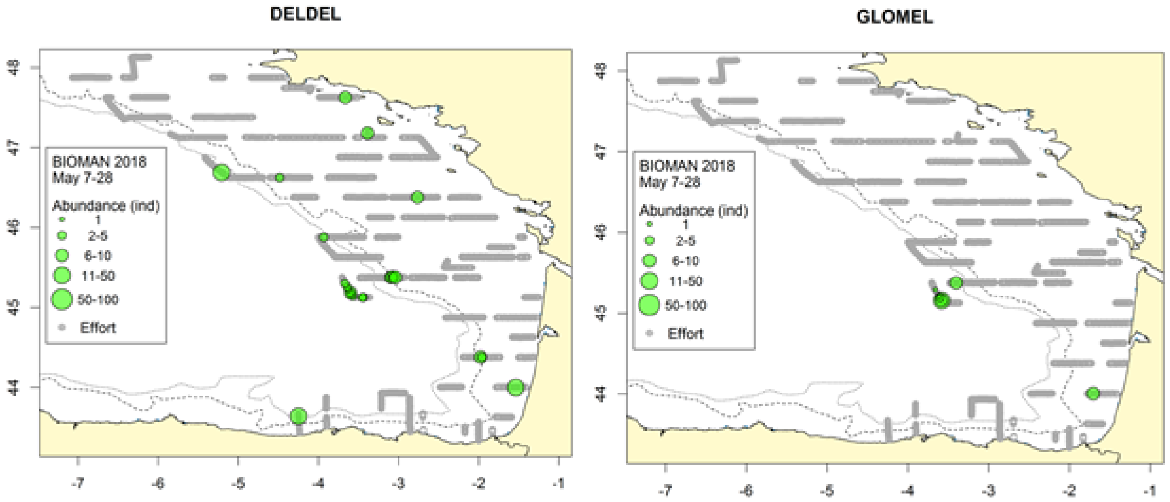


**Figure 17:** Distribution of the most abundant marine mammal species during BIOMAN 2018, (left) common dolphins and (right) stripped dolphins. Grey points represent the effort while the size of the green circles is proportional to observed abundances. The dotted and solid lines represent the isobaths of 200 m and 1000 m, respectively.

Regarding **seabirds**, 19 different species were observed. The spatial distribution of the most abundant species is showed in **Figure 18**. The most abundant species (> 15 sightings) was the northern gannet with 350 sightings (group size = 1.91 ± 9.3, a total of 669 individuals), followed by the lesser black-backed gull with 71 sightings (group size = 2.37 ± 3.45, a total of 168 individuals), the yellow-legged gull with 43 sightings (group size = 4.3 ± 7.95, a total of 185 individuals), the northern fulmar with 36 sightings (group size = 1.19 ± 0.86, a total of 43 individuals), the European storm-petrel with 19 sightings (group size = 4.74 ± 12.88, a total of 90 individuals) and the common guillemot with 16 sightings (group size = 1.12 ± 0.34, a total of 18 individuals) (**Tab.7**). We also observed great skuas, Manx shearwaters, Herring gulls, common terns, black terns, black-headed gulls, great cormorants, sooty shearwaters, Balearic shearwaters, Atlantic puffins, great black-backed gulls, a pomarine skua, and a sandwich tern (**Tab.7**).

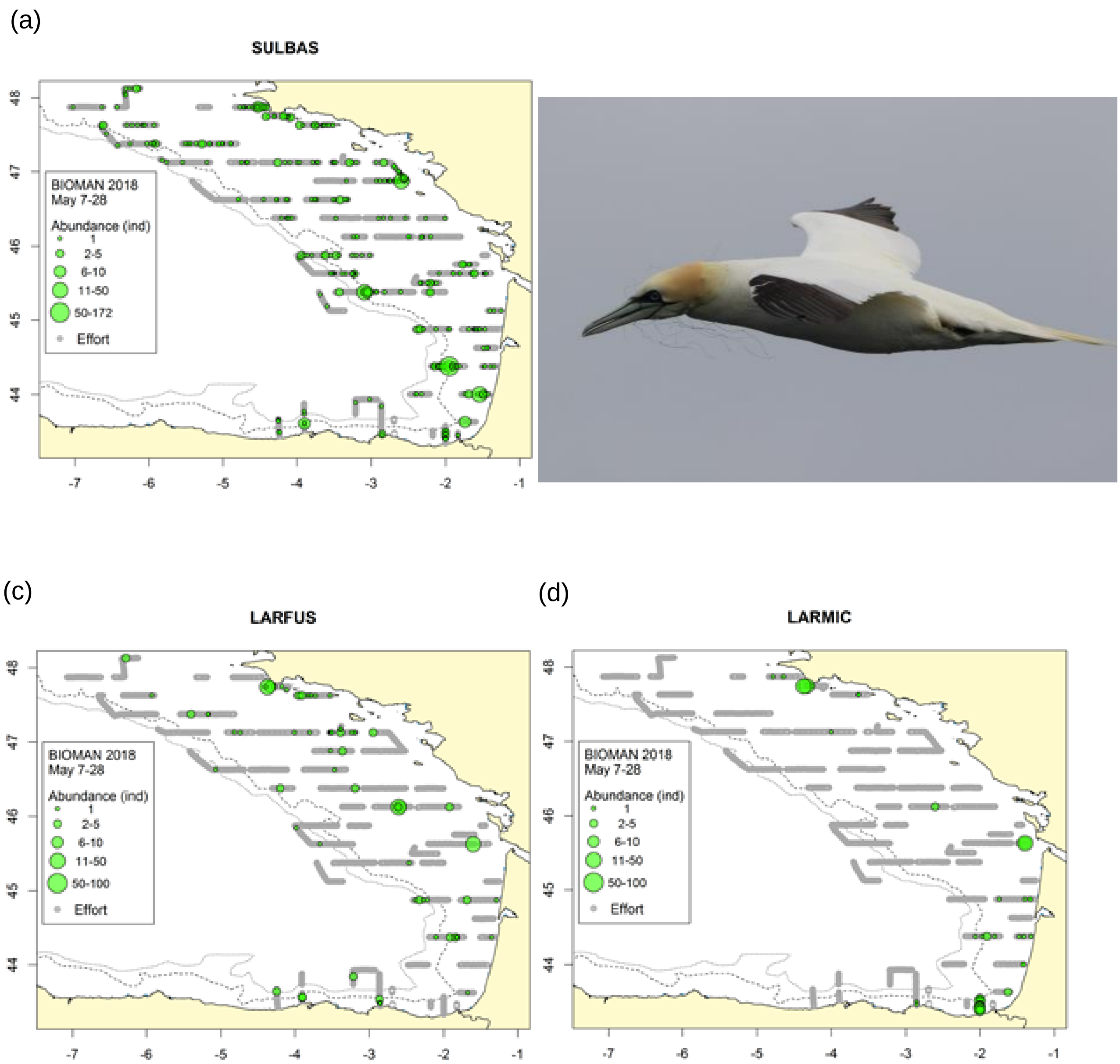


**Figure 18:** Distribution of the most abundant seabird species during BIOMAN 2018 such as (a, b) northern gannets, (c) lesser black-backed gulls and (d) yellow-legged gulls. Grey points represent the effort while the size of the green circles is proportional to observed abundances. The dotted and solid lines represent the isobaths of 200 m and 1000 m, respectively.

Northern gannets were widely distributed over the study area with aggregations observed in coastal, shelf and slope areas at northern and southern sectors of the study area (**Fig.18a&b**). The lesser black-backed gull was present in coastal and shelf areas of the French sector, with a small number of observations in the Spanish sector (**Fig.18c**), whereas the yellow-legged full was present mainly in the SE corner of the Bay of Biscay (**Fig.18d**). The northern fulmar was present north of 45ºN of latitude at the southern limit of its biogeographical range (**Fig.19a**). The European storm-petrel was more abundant at the slope areas (**Fig.19c**), whereas no clear spatial pattern was detected for common guillemots in contrast with previous years (**Fig.19d**).

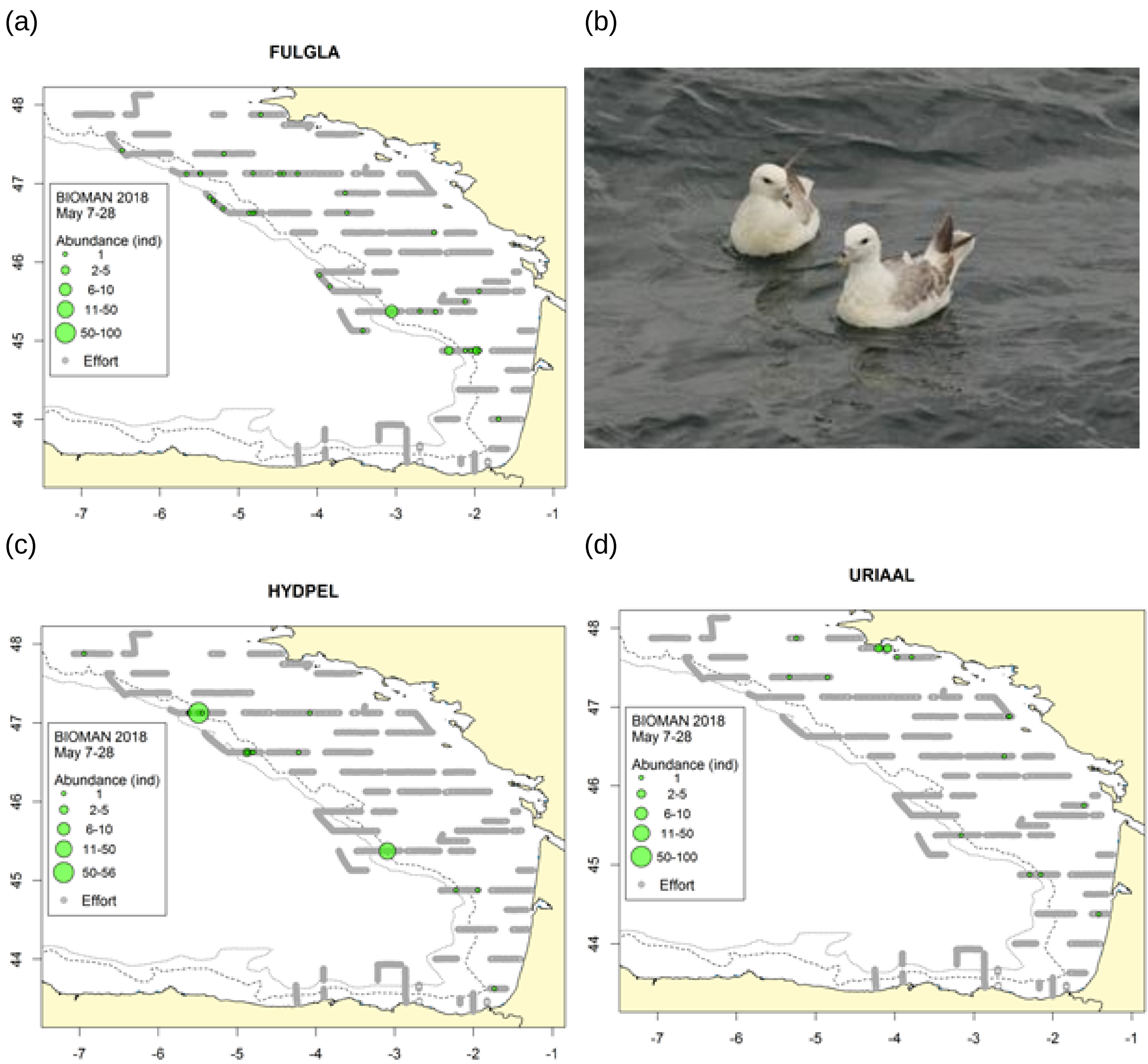


**Figure 19:** Distribution of the most abundant seabird species during BIOMAN 2018 such as (a,b) northern fulmars, (c) European storm-petrels and (d) common guillemots. Grey points represent the effort while the size of the green circles is proportional to observed abundances. The dotted and solid lines represent the isobaths of 200 m and 1000 m, respectively.

Regarding **other marine wildlife**, it is of special relevance the observation of 8 basking sharks in 5 sightings with a group size of 1.6 ± 0.89. This is the first time that the species is recorded during the BIOMAN surveys. The species is the world's second largest fish species, historically overexploited, and has been classified as Endangered following IUCN criteria in the NE Atlantic (Doherty *et al*. 2017). Recent tracking studies have identified the Bay of Biscay as an important non-breeding area where animals occupy the bathymetric range of 50-200 m depth (Doherty *et al*. 2017).

Regarding **marine debris and human activities**, we observed 5 types of marine debris and 10 different activities/items of human activities (**Tab.7**). The spatial distribution of the most abundant can be observed in **Figure 20**. The main marine debris recorded were plastic trashes with 71 sightings (group size = 1.03 ± 0.17, a total of 73 items), followed by unnatural wood, general trash, small trash and fishing trash. Plastic trashes were mostly found in the oceanic area of the eastern Bay of Biscay, between 45º and 46ºN of latitude (**Fig.20a**).

Concerning **human activities**, the activities with the highest number of sightings were the fishing buoys with 34 sightings (group size = 1.21 ± 0.64, a total of 41 items), followed by fishing boats with 22 sightings (group size = 1.14 ± 0.47, a total of 25 vessels), trawlers with 16 sightings (group size = 1.0 ± 0, a total of 16 vessels) and sailing boats with 15 sightings (group size = 1.13 ± 0.52, a total of 17 vessels)(**Tab.7**). Fishing buoys were mainly present in the French coastal (**Fig.20b**), whereas trawlers and sailing boats were scattered over the study area (**Fig.20c&d**). (**Tab.7**).

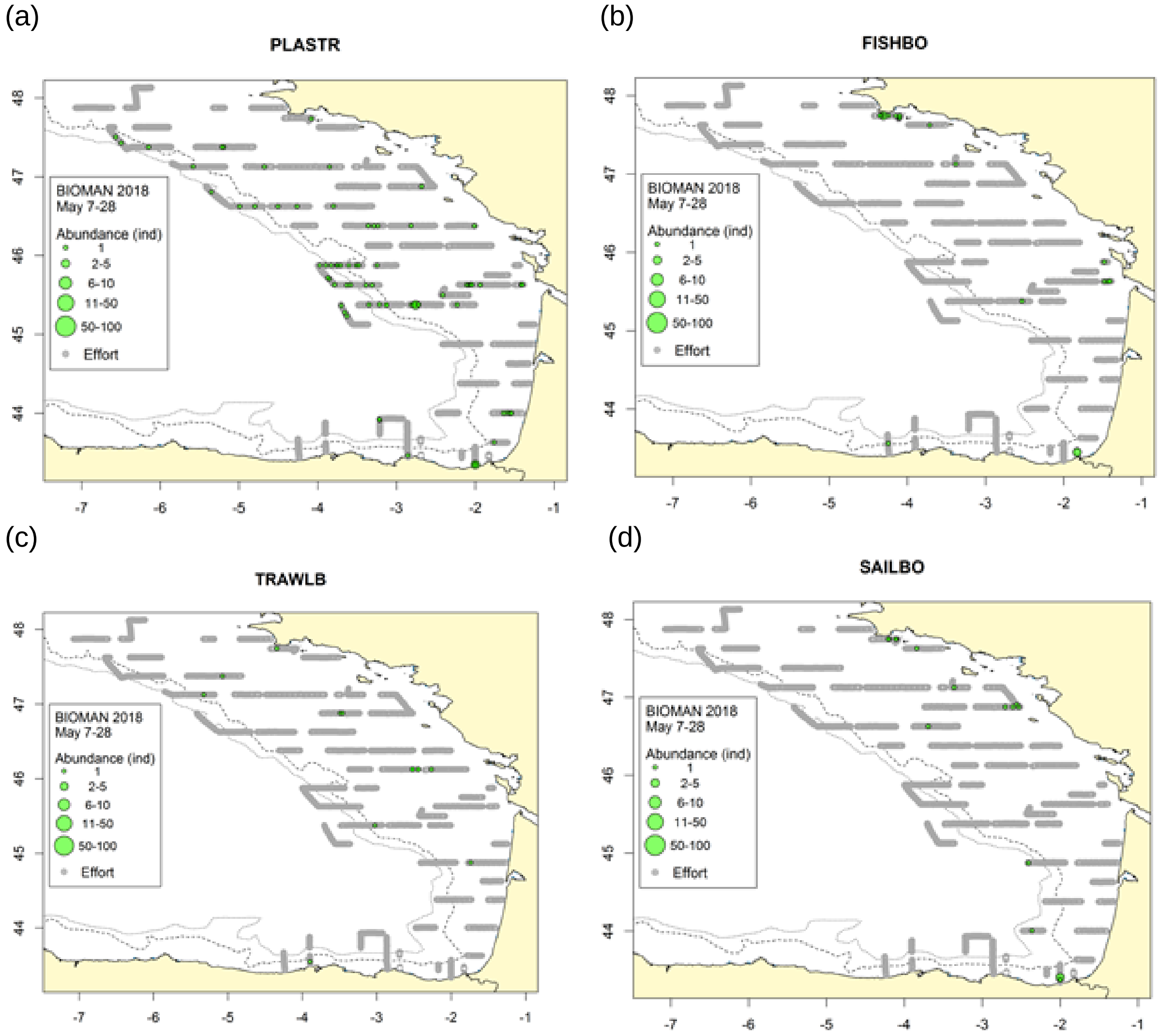


**Figure 20:** Distribution of the most abundant human activities during BIOMAN 2018 such as (a) plastic trash, (b) fishing buoys, (c) merchant ships and (d) longliners. Grey points represent the effort while the size of the green circles is proportional to observed abundances. The dotted and solid lines represent the isobaths of 200 m and 1000 m, respectively. See **Table 7** for acronyms.

## Comparing predators and human activities 2016-2018

The survey area covered by BIOMAN 2016-2018 for predators and human activities sightings is showed in **figure 21**. Even whether there is an inter-annual variability in the marine areas covered, the French continental shelf is well sampled while the Spanish continental shelf is partially covered.

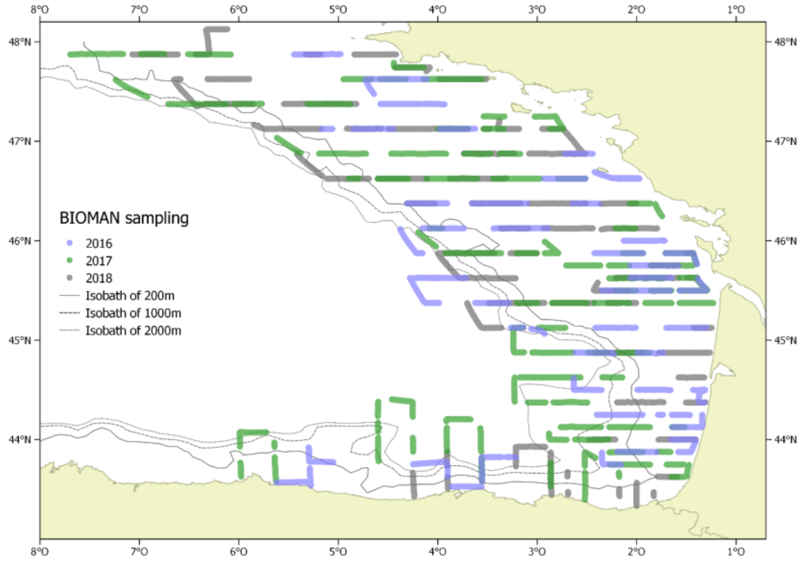


**Figure 21:** Area covered by BIOMAN surveys during 2016-2018. Blue, green and grey dotted colours represent the sampling effort in 2016, 2017 and 2018, respectively. Black lines represent the isobaths of 200, 1000 and 2000m.

The number of sightings per distance travelled and the number of predators/items/vessels per distance travelled for predators, marine debris and human activities between BIOMAN 2016, 2017 and 2018 were compared. In 2018, the number of sightings per km was the lowest compared to 2016 and 2017 for almost all predator species (**Fig.22top**). The Northern gannet was the species with a higher encounter rate for the 3-year period, followed by common guillemots, lesser black-backed gulls, northern fulmars and common dolphins with medium level of sightings. The remaining species (great skuas, European storm-petrels, Balearic shearwaters and Manx shearwaters) showed a low level of sightings.

Concerning the number of predators per km, we also observed an overall decrease for all species with higher values for lesser black-backed gulls, northern gannets, common dolphins and common guillemots, intermediate values for northern fulmar, herring and yellow-legged gulls and low levels for great skuas, European storm-petrels and Manx and Balearic shearwaters (**Fig.22 bottom**).

Regarding marine debris, the number of sightings for plastic trash per km in 2018 was the lowest compared to 2016 and 2017 (**Fig.23top**). Regarding general trash, the number of sightings per distance travelled was slightly higher in 2018 than in 2017 and lower than in 2016 (**Fig.23top**). The number of marine debris per distance travelled decreased as well for both type of trashes (**Fig.23bottom**).

In relation to other human activities, we only detected an increase in the number of sightings of fishing boats through the study period and a decrease in the fishing buoys, merchant ships, longline boats and similar values in sailing boats and trawlers (**Fig.23top**). The number of human activities showed a similar pattern as the number of sightings since the group size did not vary among years. (**Fig.23bottom**).

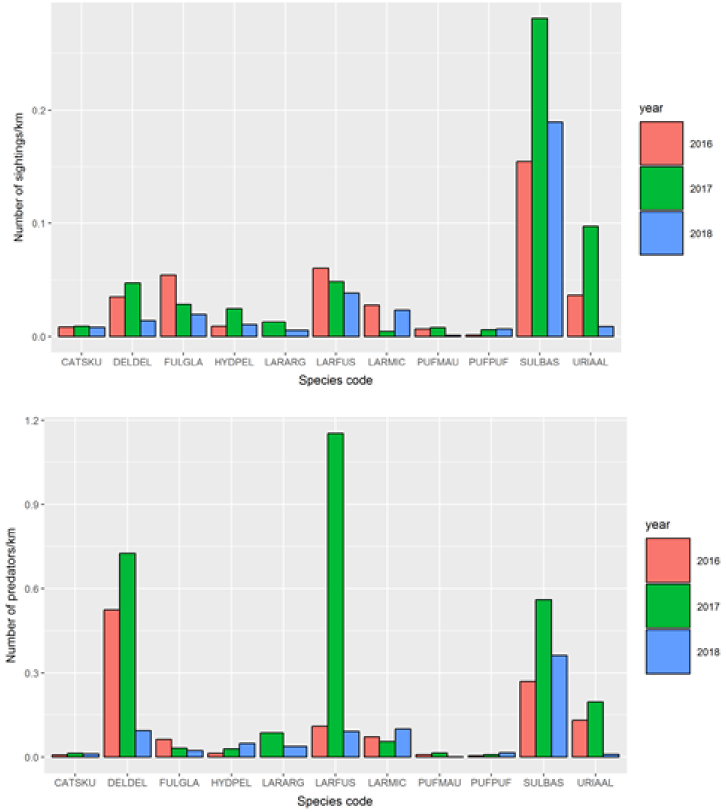


**Figure 22:** Number of predator sightings per distance travelled(km)(top). Number of predators per distance travelled (km)(bottom). 2016(pink), 2017(green) and 2018 (blue). **Table 7** for x axis acronyms.

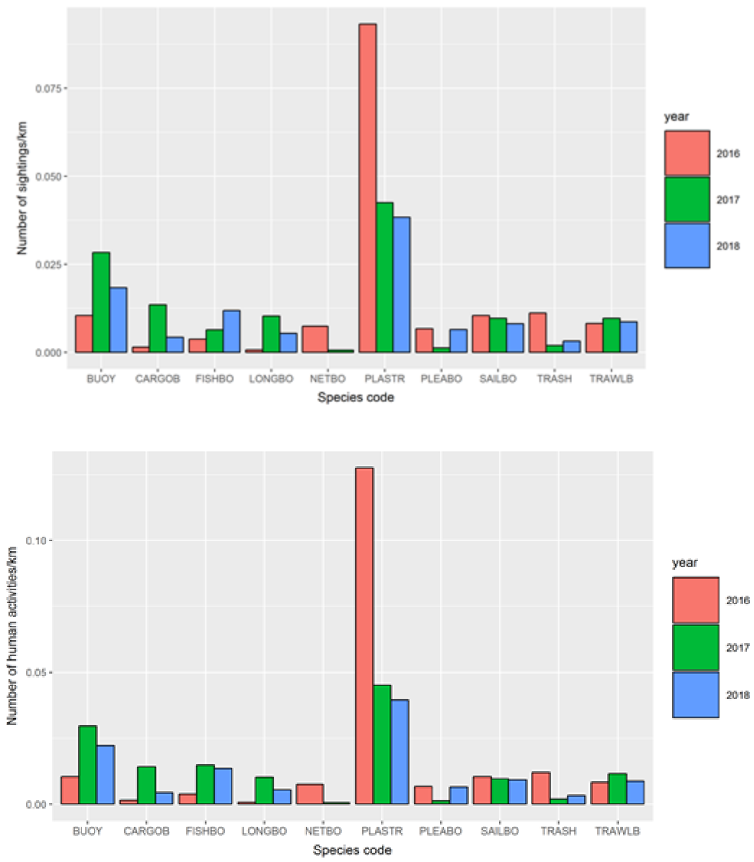


**Figure 23:** Number of sightings of marine debris/human activities per distance travelled (km)(top). Number of marine debris/human activities per distance travelled (km)(bottom). **Table 7** for x axis acronyms.

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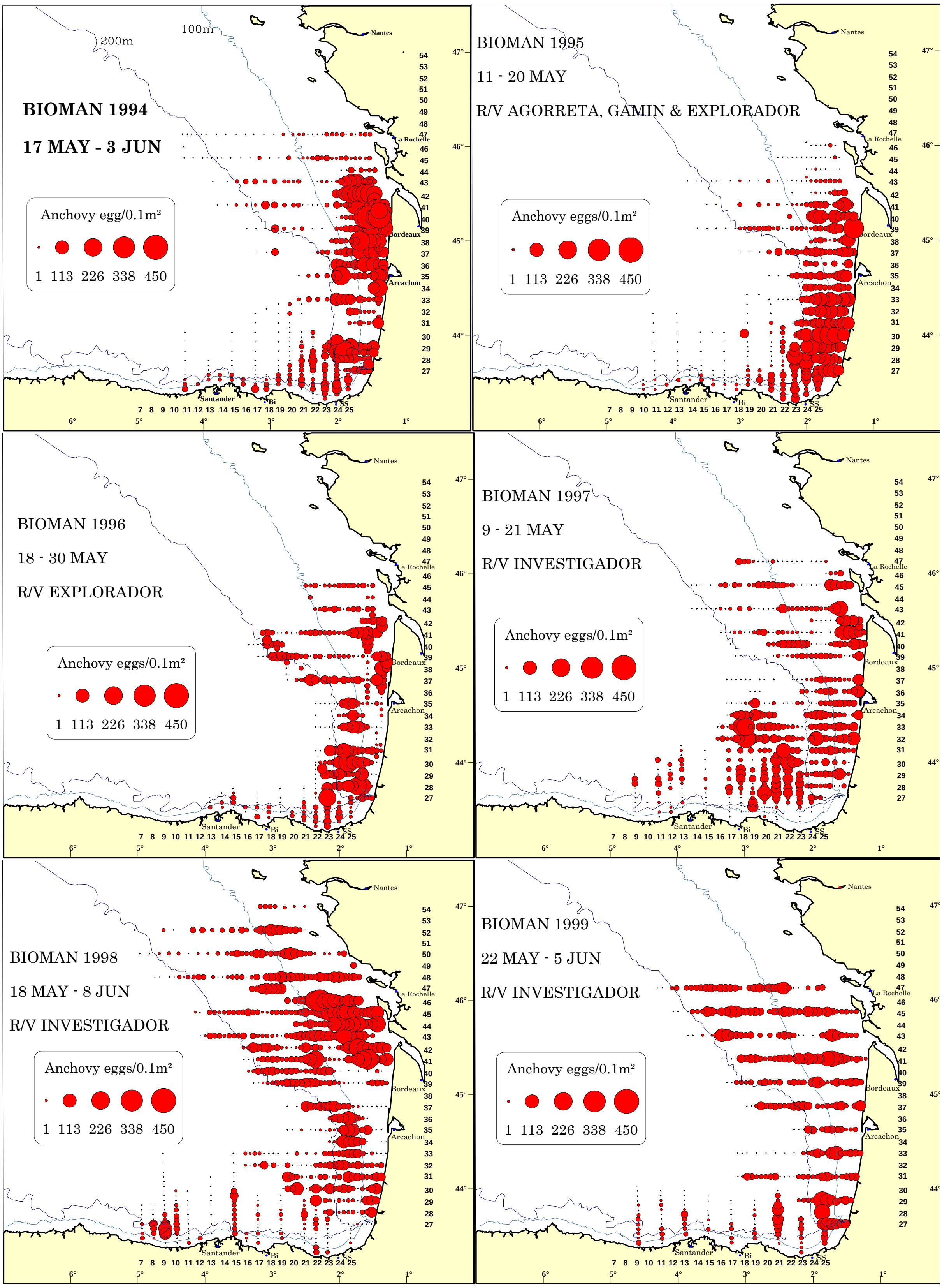
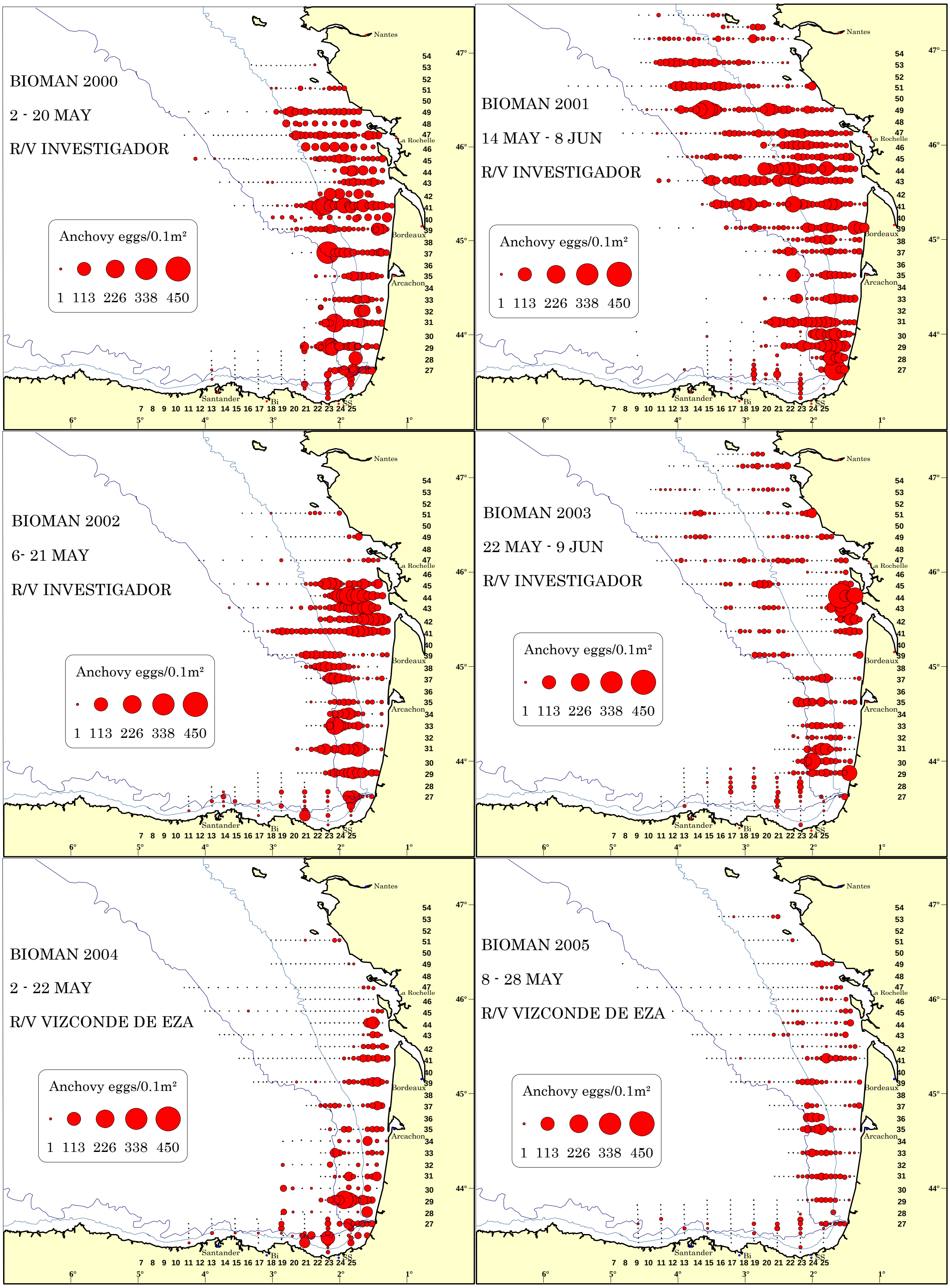
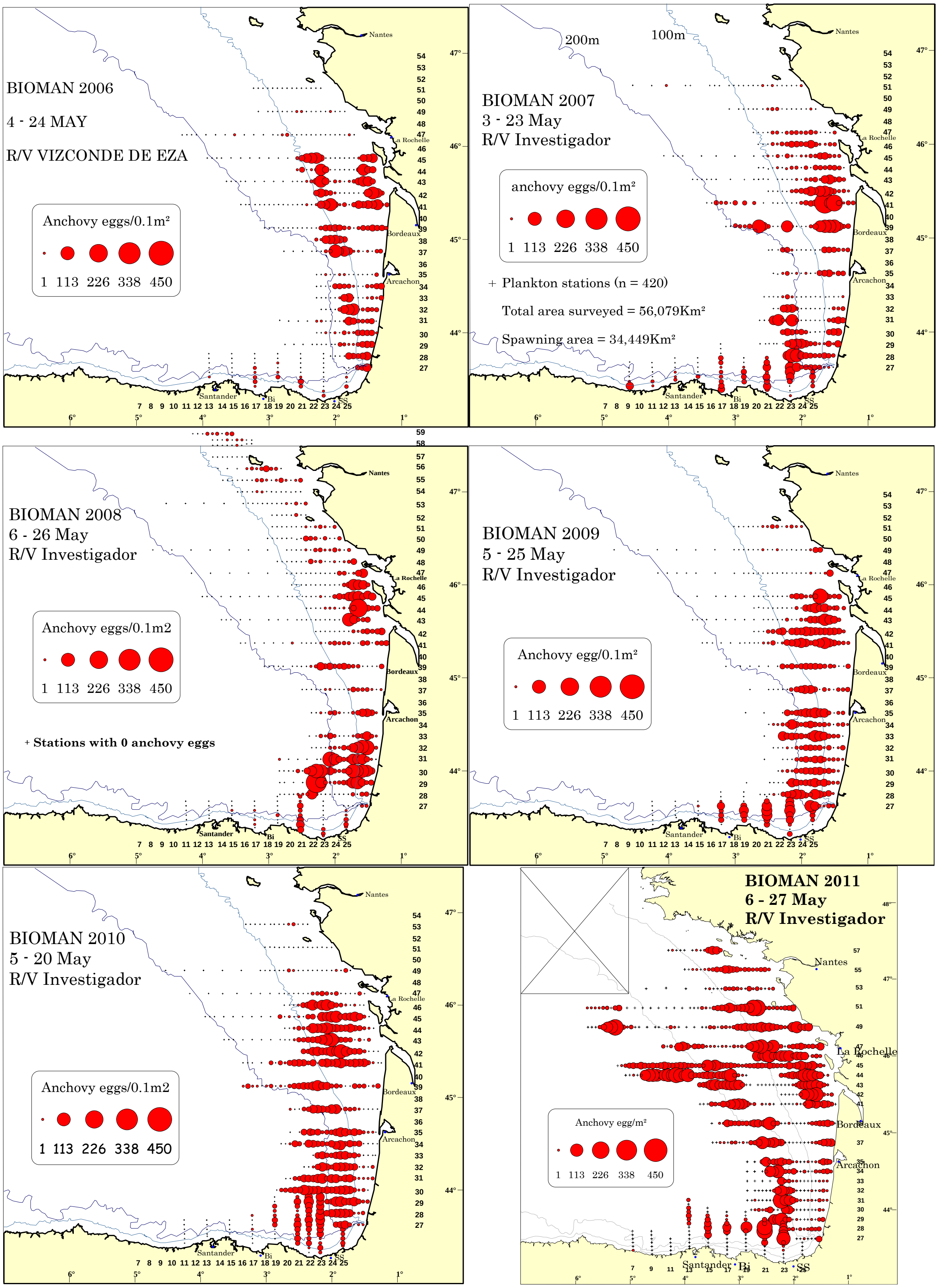


200m
100m
BIOMAN 1994
17 MAY - 3 JUN
Anchovy egg/0.1m²
1 113 226 338 450
BIOMAN 1995
11 - 20 MAY
R/V AGORRETA, GAMIN & EXPLORADOR
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 1996
18 - 30 MAY
R/V EXPLORADOR
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 1997
9 - 21 MAY
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 1998
18 MAY - 8 JUN
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 1999
22 MAY - 5 JUN
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
47°
46°
45°
44°
6°
5°
4°
3°
2°
1°


BIOMAN 2000
2 - 20 MAY
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 2001
14 MAY - 8 JUN
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 2002
6- 21 MAY
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 2003
22 MAY - 9 JUN
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 2004
2 - 22 MAY
R/V VIZCONDE DE EZA
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 2005
8 - 28 MAY
R/V VIZCONDE DE EZA
Anchovy eggs/0.1m²
1 113 226 338 450
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
47°
46°
45°
44°
6°
5°
4°
3°
2°
1°


BIOMAN 2006
4 - 24 MAY
R/V VIZCONDE DE EZA
Anchovy eggs/0.1m²
1 113 226 338 450
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
200m
100m
BIOMAN 2007
3 - 23 May
R/V Investigador
anchovy eggs/0.1m²
1 113 226 338 450
+ Plankton stations (n = 420)
Total area surveyed = 56,079Km²
Spawning area = 34,449Km²
BIOMAN 2008
6 - 26 May
R/V Investigador
Anchovy eggs/0.1m2
1 113 226 338 450
+ Stations with 0 anchovy eggs
BIOMAN 2009
5 - 25 May
R/V Investigador
Anchovy egg/0.1m²
1 113 226 338 450
BIOMAN 2010
5 - 20 May
R/V Investigador
Anchovy eggs/0.1m2
1 113 226 338 450
BIOMAN 2011
6 - 27 May
R/V Investigador
Anchovy egg/m²
1 113 226 338 450

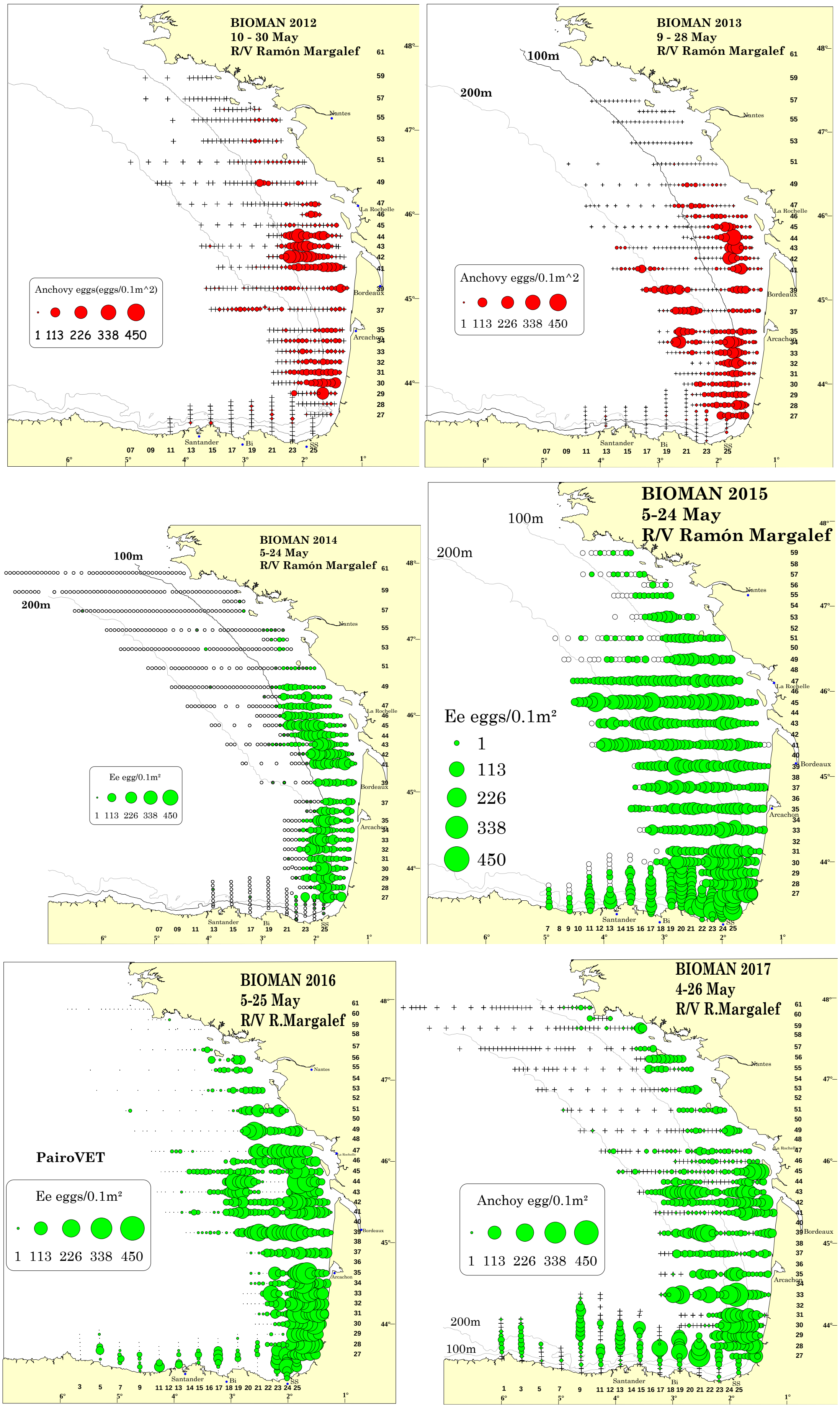
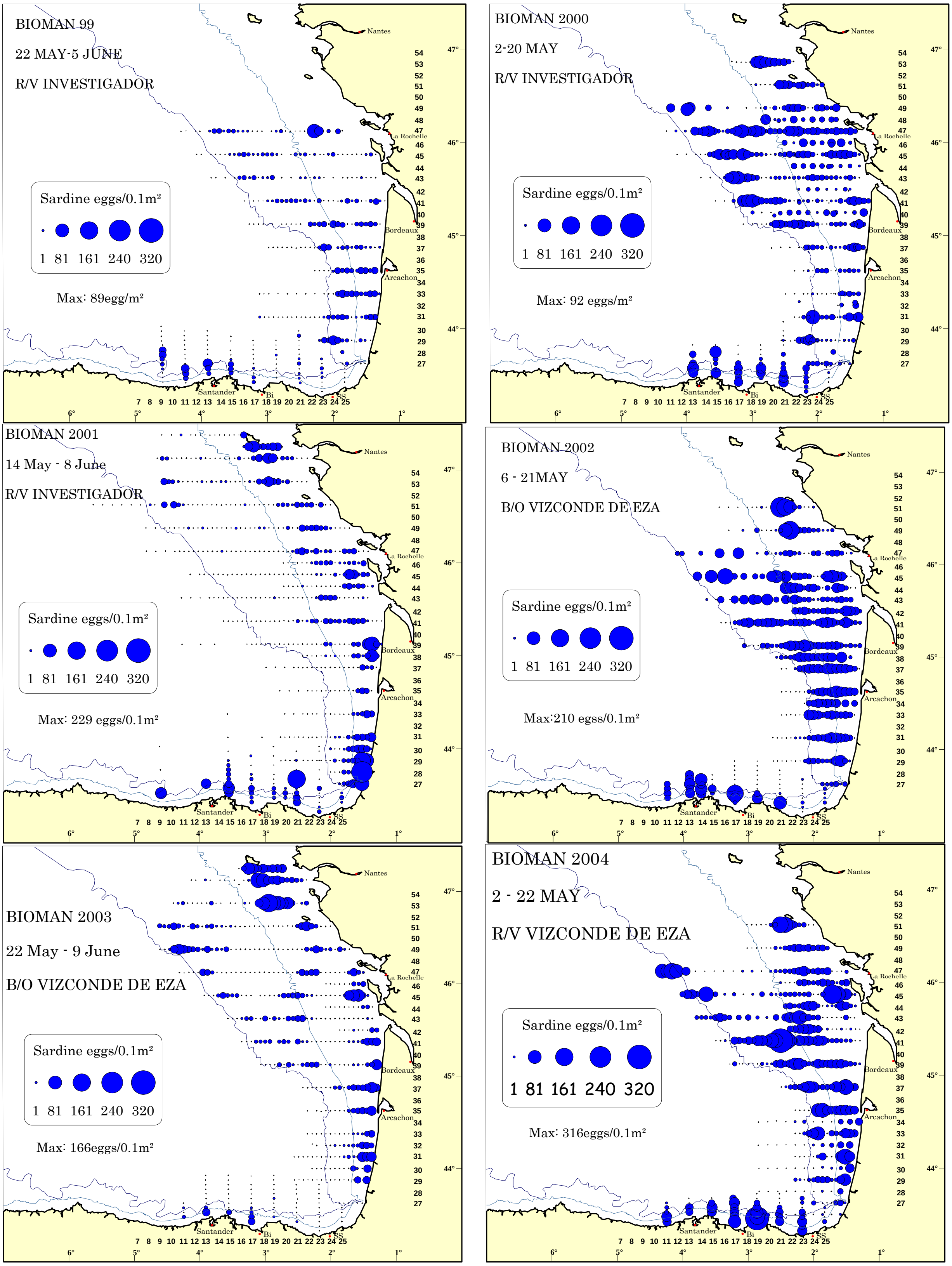
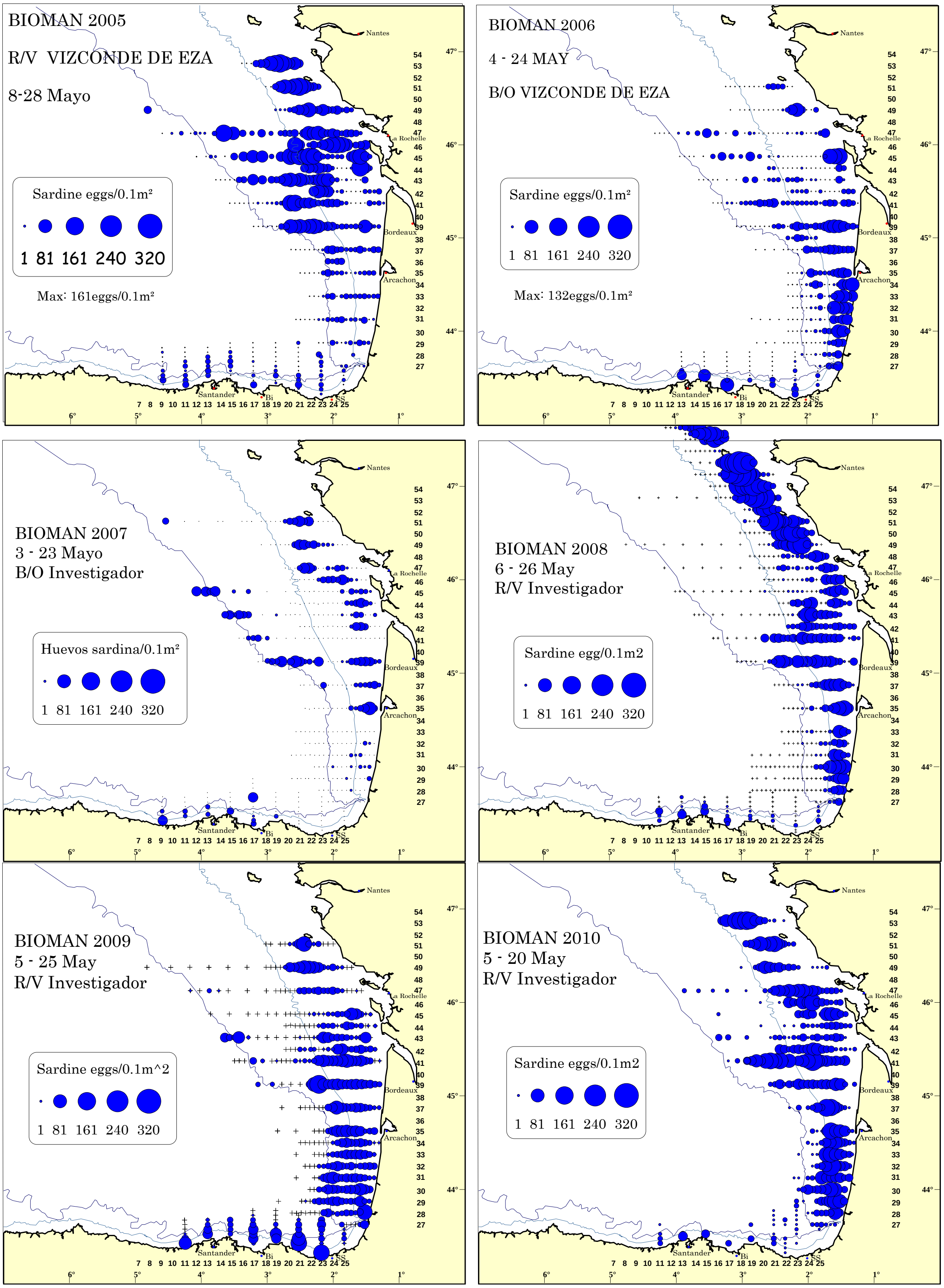
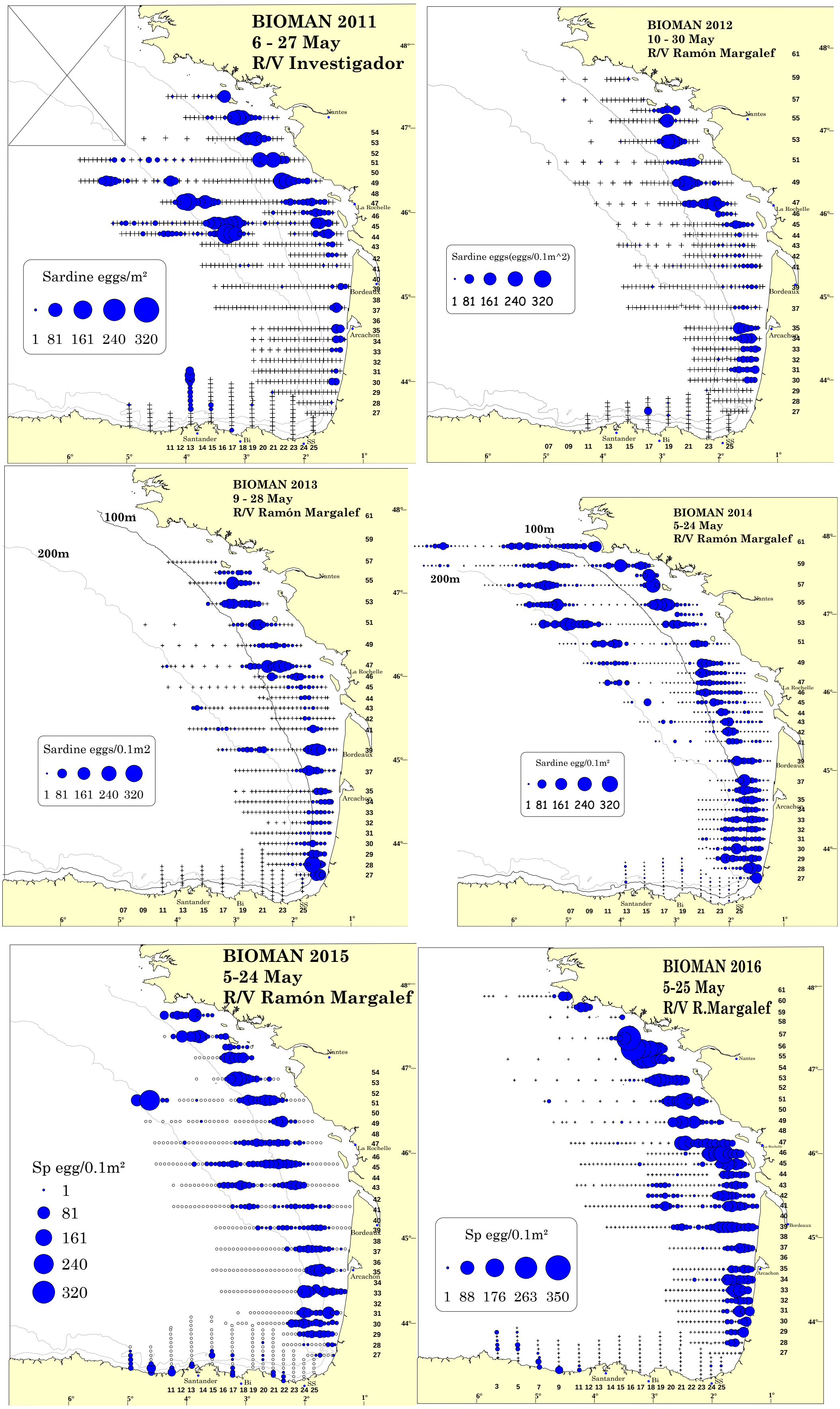



**Figure 24**: Anchovy egg distribution and abundance from 1994 to 2017.



BIOMAN 99
22 MAY-5 JUNE
R/V INVESTIGADOR
Sardine eggs/0.1m²
1 81 161 240 320
Max: 89egg/m²
BIOMAN 2000
2-20 MAY
R/V INVESTIGADOR
Sardine eggs/0.1m²
1 81 161 240 320
Max: 92 eggs/m²
BIOMAN 2001
14 May - 8 June
R/V INVESTIGADOR
Sardine eggs/0.1m²
1 81 161 240 320
Max: 229 eggs/0.1m²
BIOMAN 2002
6 - 21MAY
B/O VIZCONDE DE EZA
Sardine eggs/0.1m²
1 81 161 240 320
Max:210 egss/0.1m²
BIOMAN 2003
22 May - 9 June
B/O VIZCONDE DE EZA
Sardine eggs/0.1m²
1 81 161 240 320
Max: 166eggs/0.1m²
BIOMAN 2004
2 - 22 MAY
R/V VIZCONDE DE EZA
Sardine eggs/0.1m²
1 81 161 240 320
Max: 316eggs/0.1m²
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS


BIOMAN 2005
R/V VIZCONDE DE EZA
8-28 Mayo
Sardine eggs/0.1m²
1 81 161 240 320
Max: 161eggs/0.1m²
BIOMAN 2006
4 - 24 MAY
B/O VIZCONDE DE EZA
Sardine eggs/0.1m²
1 81 161 240 320
Max: 132eggs/0.1m²
BIOMAN 2007
3 - 23 Mayo
B/O Investigador
Huevos sardina/0.1m²
1 81 161 240 320
BIOMAN 2008
6 - 26 May
R/V Investigador
Sardine egg/0.1m2
1 81 161 240 320
BIOMAN 2009
5 - 25 May
R/V Investigador
Sardine eggs/0.1m^2
1 81 161 240 320
BIOMAN 2010
5 - 20 May
R/V Investigador
Sardine eggs/0.1m2
1 81 161 240 320
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
47°
46°
45°
44°
6°
5°
4°
3°
2°
1°


BIOMAN 2011
6 - 27 May
R/V Investigador
Sardine eggs/m²
1 81 161 240 320
BIOMAN 2012
10 - 30 May
R/V Ramón Margalef
Sardine eggs(eggs/0.1m^2)
1 81 161 240 320
BIOMAN 2013
9 - 28 May
R/V Ramón Margalef
100m
200m
Sardine eggs/0.1m2
1 81 161 240 320
BIOMAN 2014
5-24 May
R/V Ramón Margalef
100m
200m
Sardine egg/0.1m²
1 81 161 240 320
BIOMAN 2015
5-24 May
R/V Ramón Margalef
Sp egg/0.1m²
1
81
161
240
320
BIOMAN 2016
5-25 May
R/V R.Margalef
Sp egg/0.1m²
1 88 176 263 350
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS

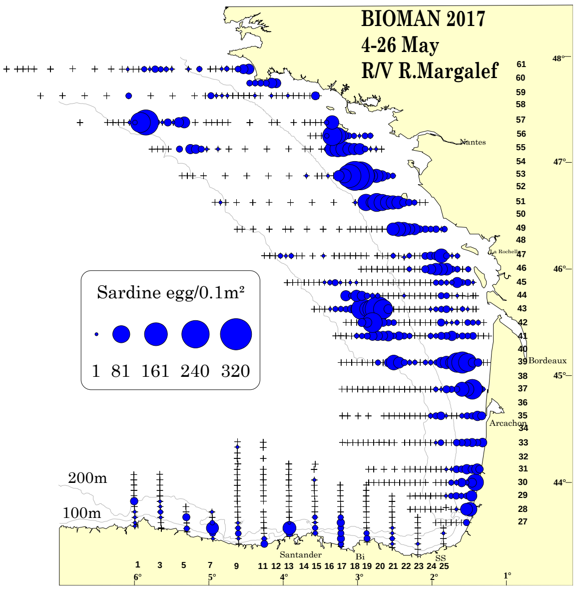



**Figure 25**: Sardine egg distribution and abundance from 1999 to 2017.

**Table 7:** List of taxa observed during BIOMAN 2018

| Group | Common_name | Scientific_name | code_esp | Number_of_sightings | Group_size | Total_sum |
|---|---|---|---|---|---|---|
| **Seabirds** | Northern gannet | *Morus bassanus* | SULBAS | 350 | 1.91 ± 9.3 | 669 |
| | Lesser black-backed gull | *Larus fuscus* | LARFUS | 71 | 2.37 ± 3.45 | 168 |
| | Yellow-legged gull | *Larus michahellis* | LARMIC | 43 | 4.3 ± 7.95 | 185 |
| | Northern fulmar | *Fulmarus glacialis* | FULGLA | 36 | 1.19 ± 0.86 | 43 |
| | European storm-petrel | *Hydrobates pelagicus* | HYDPEL | 19 | 4.74 ± 12.88 | 90 |
| | Common guillemot | *Uria aalge* | URIAAL | 16 | 1.12 ± 0.34 | 18 |
| | Great skua | *Stercorarius skua* | CATSKU | 15 | 1.4 ± 0.91 | 21 |
| | Manx shearwater | *Puffinus puffinus* | PUFPUF | 12 | 2.33 ± 2.71 | 28 |
| | European herring gull | *Larus argentatus* | LARARG | 10 | 7 ± 12.37 | 70 |
| | Common Tern | *Sterna hirundo* | STEHIR | 5 | 1.8 ± 1.3 | 9 |
| | Black Tern | *Chlidonias niger* | CHLNIG | 2 | 3 ± 1.41 | 6 |
| | Black-headed gull | *Chroicocephalus ridibundus* | LARRID | 2 | 2 ± 1.41 | 4 |
| | Great cormorant | *Phalacrocorax carbo* | PHACAR | 2 | 2.5 ± 0.71 | 5 |
| | Sooty shearwater | *Ardenna grisea* | PUFGRI | 2 | 1 ± 0 | 2 |
| | Balearic shearwater | *Puffinus mauretanicus* | PUFMAU | 2 | 1 ± 0 | 2 |
| | Atlantic puffin | *Fratercula arctica* | FRAARC | 1 | | 1 |
| | Great black-backed gull | *Larus marinus* | LARMAR | 1 | | 1 |
| | Pomarine skua | *Stercorarius pomarinus* | STEPOM | 1 | | 1 |
| | Sandwich Tern | *Thalasseus sandvicensis* | STESAN | 1 | | 2 |
| | Total | | | 591 | | 1325 |
| **Marine mammals** | Common dolphin | *Delphinus delphis* | DELDEL | 26 | 6.69 ± 6.03 | 174 |
| | Striped dolphin | *Stenella coeruleoalba* | STECOE | 3 | 20.67 ± 21.13 | 62 |
| | Long-finned pilot whale | *Globicephala melas* | GLOMEL | 7 | 6.86 ± 4.67 | 48 |
| | Fin whale | *Balaenoptera physalus* | BALPHY | 2 | 1 ± 0 | 2 |
| | Bottlenose dolphin | *Tursiops truncatus* | TURTRU | 1 | | 2 |
| | Total | | | 39 | | 288 |
| **Other Marine Wildlife** | basking shark | *Cetorhinus maximus* | CETMAX | 5 | 1.6 ± 0.89 | 8 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Sunfish | *Mola mola* | MOLMOL | 4 | 1.25 ± 0.5 | 5 |
| **Marine debris** | Plastic trash | | PLASTR | 71 | 1.03 ± 0.17 | 73 |
| | Unnatural wood | | WOODTR | 9 | 1 ± 0 | 9 |
| | General trash | | TRASH | 6 | 1 ± 0 | 6 |
| | Small trash | | SMALTR | 1 | | 1 |
| | Fishing trash | | FISHTR | 1 | | 1 |
| | Total | | | 88 | | 90 |
| **Human activity** | Fishing buoy | | BUOY | 34 | 1.21 ± 0.64 | 41 |
| | Fishing boat | | FISHBO | 22 | 1.14 ± 0.47 | 25 |
| | Trawler | | TRAWLB | 16 | 1 ± 0 | 16 |
| | Sailing boat | | SAILBO | 15 | 1.13 ± 0.52 | 17 |
| | Pleasure boat | | PLEABO | 12 | 1 ± 0 | 12 |
| | Longliner | | LONGBO | 10 | 1 ± 0 | 10 |
| | Merchant ship | | CARGOB | 8 | 1 ± 0 | 8 |
| | Administrative boat | | ADMIBO | 1 | | 1 |
| | Platform | | PLATFO | 1 | | 1 |
| | Tanker | | TANKER | 1 | | 1 |
| | Total | | | 120 | | 132 |
| **Land Bird** | Dunlin | *Calidris alpina* | CALALP | 4 | 3.25 ± 2.06 | 13 |
| | House martin | *Delichon urbica* | DELURB | 2 | 1 ± 0 | 2 |
| | Barn swallow | *Hirundo rustica* | HIRRUS | 2 | 1 ± 0 | 2 |
| | Swift | *Apus apus* | APUAPU | 1 | | 1 |
| | Sanderling | *Calidris alba* | CALALB | 1 | | 1 |
| | Curlew Sandpiper | *Calidris ferruginea* | CALFER | 1 | | 5 |
| | NA | *Limicole spp* | LIMICO | 1 | | 12 |
| | Whimbrel | *Numenius phaeopus* | NUMPHA | 1 | | 1 |
| | Total | | | 13 | | 37 |

## Annex 3.3: PELAGO18 acoustic survey in the Atlantic Iberian Waters of ICES area 9a (River Minho - Cape Trafalgar)

*Please see report on next page.*

*Working Document presented at WGACEGG, 19-23 November 2018, Nantes, France*

# PELAGO18 acoustic survey in the Atlantic Iberian Waters of ICES area 9a (River Minho - Cape Trafalgar)

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**Abstract**

PELAGO18 survey was carried out onboard RV "Noruega" from 26th April to 1st June 2018. The main objective of the PELAGO18 survey was to describe the sardine and anchovy spatial distributions and to estimate their abundance off the Portuguese and the Spanish Gulf of Cadiz shelves. The estimated sardine biomass was 172 thousand tons for the whole area, representing a significant increase in relation to the PELAGO17 survey (81 thousand tons) and a similar estimate to the one obtained during the PELAGO16 survey (172 thousand tons) but with different partition between zones. The OCS zone was the area where the strongest increase of biomass was observed, the 2018 estimate was three-fold higher than the one obtained during the PELAGO17. A considerable increase in the sardine biomass, mainly small fish, was also observed in the area of Cadiz Bay. There was also a raise in the anchovy biomass, in the whole area, in relation to the PELAGO17 survey (78 thousand tons in 2018, comparing with 29 thousand tons in 2017) but it was mainly due to the contribution of the fish in the OCN zone, where large schools of the species were observed. Accordingly, the anchovy egg abundances obtained with the CUFES system were very high for the NW region. The density was in fact the highest of the whole time series, the anchovy eggs represented 75% of the total eggs collected and 44% were in the NW shelf. Sardine eggs represented only 8% of the total eggs in the CUFES samples and 43% were observed in the NW. The proportion of anchovy versus sardine eggs in 2018 is also partially a consequence of the survey timing, mainly during May, when the sardine spawning season is closer to its end whereas the anchovy season is well underway.

## 1. Background and survey summary

The acoustic surveys of the PELAGO series are funded via EU-DCF and national programmes and are coordinated with the spring acoustic surveys from Spain and France, and discussed and reported within ICES - WGACEGG (Working Group on Acoustics and Egg Surveys). The Portuguese acoustic survey, takes place each year during spring covering the shelf waters of Portugal and Cadiz Bay. The main objectives of PELAGO surveys include monitoring the abundance distribution through echo-integration, and the study of several biological parameters for sardine (*Sardina pilchardus*), anchovy (*Engraulis encrasicolus*), mackerel (*Scomber scombrus*), chub-mackerel (*Scomber colias*), horse-mackerel (*Trachurus trachurus*) and other small pelagic fishes. Surveying also considers continuous observations of fish eggs and larvae along the acoustic transects (CUFES - Continuous Underway Fish Egg Sampler) and hydrological and biological characterization of the water column. Additionally, census of marine birds and mammals are conducted during the survey trajectory. A summary of the work developed during the surveys, by geographical area, is presented in Table 1.1.

**Table 1.1. PELAGO18 survey summary information by area.**

| | OCN (NW) | OCS (SW) | ALG (S) | Cadiz (S) |
|---|---|---|---|---|
| Vessel | Noruega | Noruega | Noruega | Noruega |
| Dates | 28/04-06/05 | 07-22/05 | 22-26/05 | 27-30/05 |
| SURVEY EGGS & HYDROGRAPHY | **OCN (NW)** | **OCS (SW)** | **ALG (S)** | **Cadiz (S)** |
| SST (ºC) max/mean/min | 16.0/14.2/12.8 | 16.3/15.1/13.5 | 19.9/17.8/16.0 | 20.4/19.2/18.30 |
| CTDF casts | 25 | 27 | 20 | 15 |
| Transects CUFES PELAGO | 17 | 29 | 14 | 11 |
| CUFES samples – PELAGO | 156 | 189 | 88 | 100 |
| Tot eggs PIL (positive samples) | 12174(96) | 12571(86) | 195(37) | 2965(41) |
| Tot eggs ANE (positive samples) | 116634(136) | 16941(142) | 4287(49) | 21869(69) |
| Max eggs/m3 per sample PIL | 156.76 | 664.04 | 2.19 | 81.90 |
| Max eggs/m3 per sample ANE | 491.59 | 202.51 | 82.16 | 334.46 |
| SURVEY ACOUSTICS & FISH | **OCN (NW)** | **OCS (SW)** | **ALG (S)** | **Cadiz** |
| Number of acoustics transects (nm) | 17(453) | 29(415) | 14(166) | 11(194) |
| Number hauls R/V (pelagic/bottom) | 9/5 | 7/8 | 8/3 | 7/4 |
| Number hauls (CV) | 18 | 9 | 4 | 0 |
| Number RV (+) trawls - PIL | 8 | 7 | 7 | 6 |
| Number RV (+) trawls - HOM | 7 | 10 | 4 | 2 |
| Number RV (+) trawls - MAC | 5 | 3 | 1 | 9 |
| Number RV (+) trawls - MAS | 4 | 10 | 7 | 9 |
| Number RV (+) trawls - ANE | 8 | 1 | 1 | 9 |
| Depth range (m) in (pelagic/bottom) RV fishing operations | 9-95/ 45-121 | 35-56/ 43-149 | 24-61/ 73-147 | 19-46/ 76-108 |
| Total number fish sampled - PIL | 2031 | 1135 | 801 | 597 |
| Total number fish sampled - HOM | 403 | 1085 | 69 | 12 |
| Total number fish sampled - MAC | 91 | 4 | 6 | 84 |
| Total number fish sampled - MAS | 66 | 1021 | 960 | 459 |
| Total number fish sampled - ANE | 1945 | 2 | 28 | 887 |
| Number otoliths collected - PIL | 511 | 278 | 358 | 109 |
| Number otoliths collected – HOM | 98 | 86 | 24 | - |
| Number otoliths collected - MAC | 27 | - | - | 25 |
| Number otoliths collected - MAS | 53 | 229 | 192 | 155 |
| Number otoliths collected - ANE | 106 | - | 28 | 186 |

RV – Research vessel
CV – Comercial vessel

## 2. Acoustic Survey

### *Material and methods*

*Acoustics*

Survey execution and abundance estimation followed the methodologies adopted by the ICES WGACEGG. The survey area, over the shelf until the 200 m isobath, was covered following a parallel grid with a mean distance between transects of 8 nautical miles. Average survey speed was 8 knots and the acoustic signals were integrated over one nautical mile intervals. Echo integration was carried out with a 38 kHz Simrad EK60 scientific echo sounder while the 120 KHz sounder was used to assist in the echogram scrutiny process. The acoustic data was recorded in MOVIES+ (Weill *et al*., 1993), which was also used to integrate the fish acoustic energy. The echogram bottom was manually corrected prior to the acoustic energy extraction. An acoustic calibration with a copper sphere was carried out, following the standard procedures (Foote *et al.*, 1981). For presentation purposes and results comparison, the surveyed area was divided, as usual, into 4 sub-areas or regions: OCN (from Caminha to Nazaré), OCS (from Nazaré to Cape S. Vicente), Algarve (from Cape S. Vicente to V. R. Santo António) and Cadiz (from V. R. Santo António to Cape Trafalgar).

*Adult fish*

The fishing data was used for biological purposes but also to identify the species and to split the acoustic energy by species and by length, within each species. Fishing was carried out according to the echogram information. Nevertheless, due to the presence of fixed commercial fishing gears or irregular and rocky bottoms, it was not always possible to make hauls in some areas. Biological sampling of sardine, anchovy, horse-mackerel, mackerel and chub-mackerel was performed whenever the species were present in the hauls. In addition, otoliths were collected for sardine, anchovy, horse-mackerel, mackerel and chub-mackerel. Otoliths are used for age reading and for the production of Age Length Keys (ALK's). For sardine and anchovy, the abundance (x 1 000) by age group and area is estimated from the combination of the ALK and the estimates of abundance at length from the echo-integration in each area.

During the PELAGO18 4 purse-seiners were rented to work along RV Noruega in the Portuguese coastal waters. The fishing operations undertaken by the purse-seiners, were always coordinated and realised on demand from the scientific team onboard RV Noruega and an element from IPMA was always on board the purse-seiners to follow and guide the operations and carry out the fish sampling. The samples were collected before the hauling of the net when a small random portion of the catch, of less than half of a net bag ≈ 20 kg, was taken. After, the fishermen deliberately lowered the net by the floating line to release the fish.

**Results**

***Fish trawling, biological data, and pelagic community***

To collect the biological data, 82 fishing hauls were undertaken, of which 51 were carried out by the RV (31 with the pelagic net and 20 with the bottom trawl) and 31 were performed by the purse-seiners. During the PELAGO18, 55% of the hauls were positive for sardine, but the latter represented only about 14.4% of the fish caught (in numbers), their availability in the trawls continued the downward trend that has been observed in the more recent surveys; sardine were caught in very low numbers in the Occidental North (OCN) area (0.41%), and were present mainly in the hauls carried out in Occidental South and Southern (ALG, CAD; 44.7% and 64.2%, respectively) areas (Figure 2.1). Anchovy were present in 37.3% of the hauls, almost exclusively concentrated in Occidental North (OCN) and South areas (CAD), representing 32.4% (in numbers) of the fish caught during the survey (Figure 2.1). As for the other pelagic fish (horse-mackerel, mackerel and chub mackerel), they were caught in low numbers (0.03-3.0 % in number), with chub mackerel being present mainly in Algarve area.

***Sardine and anchovy biomass, abundance and distribution***

Figure 2.2 and figure 2.3 show, respectively, sardine and anchovy distributions of acoustic energy; both species presenting a patchy pattern. In particular, sardine energy in the Occidental North (OCN) area was very scarce, restricted to only a few transects. Main sardine acoustic energy was located between Peniche and Lisboa, South of Sines, in the eastern part of Algarve and in Cadiz Bay (Figure 2.2). As for anchovy, acoustic energy in the West coast was concentrated in the area between Porto and Nazaré, while in the South coast, it was located exclusively to the east of Faro, and mainly in the Cadiz Spanish waters (Figure 2.3).

The estimated sardine biomass was 172 thousand tons for the whole area, representing a significant increase in relation to the PELAGO17 survey (81 thousand tons) and of the same level of the PELAGO16 survey (172 thousand tons) but with different partition between zones. The OCS zone was the area with the strongest increase in biomass, which tripled in relation to PELAGO17. Cadiz area showed also a big increase in sardine biomass (see Table 2.1).

Anchovy biomass also increased, in the whole area, in relation to the PELAGO17 survey (77.9 thousand tons in 2018, comparing with 29 thousand tons in 2017), but this raise was mainly due to the contribution of the OCN zone. The total biomass of anchovy estimated represented an estimated abundance of 7001 million fish. The occurrence of this species was detected in the OCN, ALG and CAD areas, being most abundant in the OCN (4844.6 million fish, 54.4 thousand tons) and much less abundant in ALG (299.6 million fish, 4.3 thousand tons) (Table 2.2).

Figure 2.4 shows the sardine biomass (thousand tonnes) and abundance (billion fish) evolution along the time series since year 2005, in each zone. Figure 2.5 shows the anchovy biomass evolution since the year 2005, for the Portuguese West coast and for the South (Algarve and Gulf of Cadiz together).

**Table 2.1. Pelago18: Estimated sardine abundance and biomass by area and total.**

| Sardine | OCN | OCS | ALG | CAD | TOTAL |
|---|---|---|---|---|---|
| Biomass (ton) | 14954 | 98463 | 22627 | 35934 | 171978 |
| Abundance (million) | 1256799 | 1669753 | 1097425 | 5582859 | 9606836 |

**Table 2.2. Pelago18: Estimated anchovy abundance and biomass by area and total.**

| Anchovy | OCN | OCS | ALG | CAD | TOTAL |
|---|---|---|---|---|---|
| Biomass (ton) | 54437 | - | 4328 | 19145 | 77910 |
| Abundance (million) | 4844655 | - | 299574 | 1857016 | 7001245 |

***Sardine: length and age composition***

Figure 2.6 presents the length composition of sardine biomass and abundance for each area surveyed. Small sardines (<16 cm) were observed in the OCN zone and in the Cadiz Spanish waters. Algarve showed a mixture of young and adult sardine and in the OCS zone sardine was mainly adult.

*Age composition*

Figure 2.7 presents the age distribution of sardine biomass and abundance per area surveyed. In the OCN area, sardine ages ranged from 0 to 7 years, but the main cohorts belonged to 0 and 1 years old sardine. The OCS area showed mainly sardines with 2 and 3 years of age. In the Algarve the sardines observed were a mixture of 0, 1 and 2 years-olds. In Cadiz area only zero years old sardine were found.

***Anchovy: length and age composition***

Anchovy abundance and biomass estimates by age composition in each of the three anchovy occurrence areas are presented in Figure 2.8. In the OCN zone the anchovy length mode was around 10.5 cm, in ALG was 12.5 cm and in CAD the modal length was 11.5 cm.

*Age composition*

All the anchovy found were of age 1 in OCN and Algarve. In Cadiz area, although the main cohort was age 1, there were a few age 2 and 3 anchovies (Figure 2. 9).

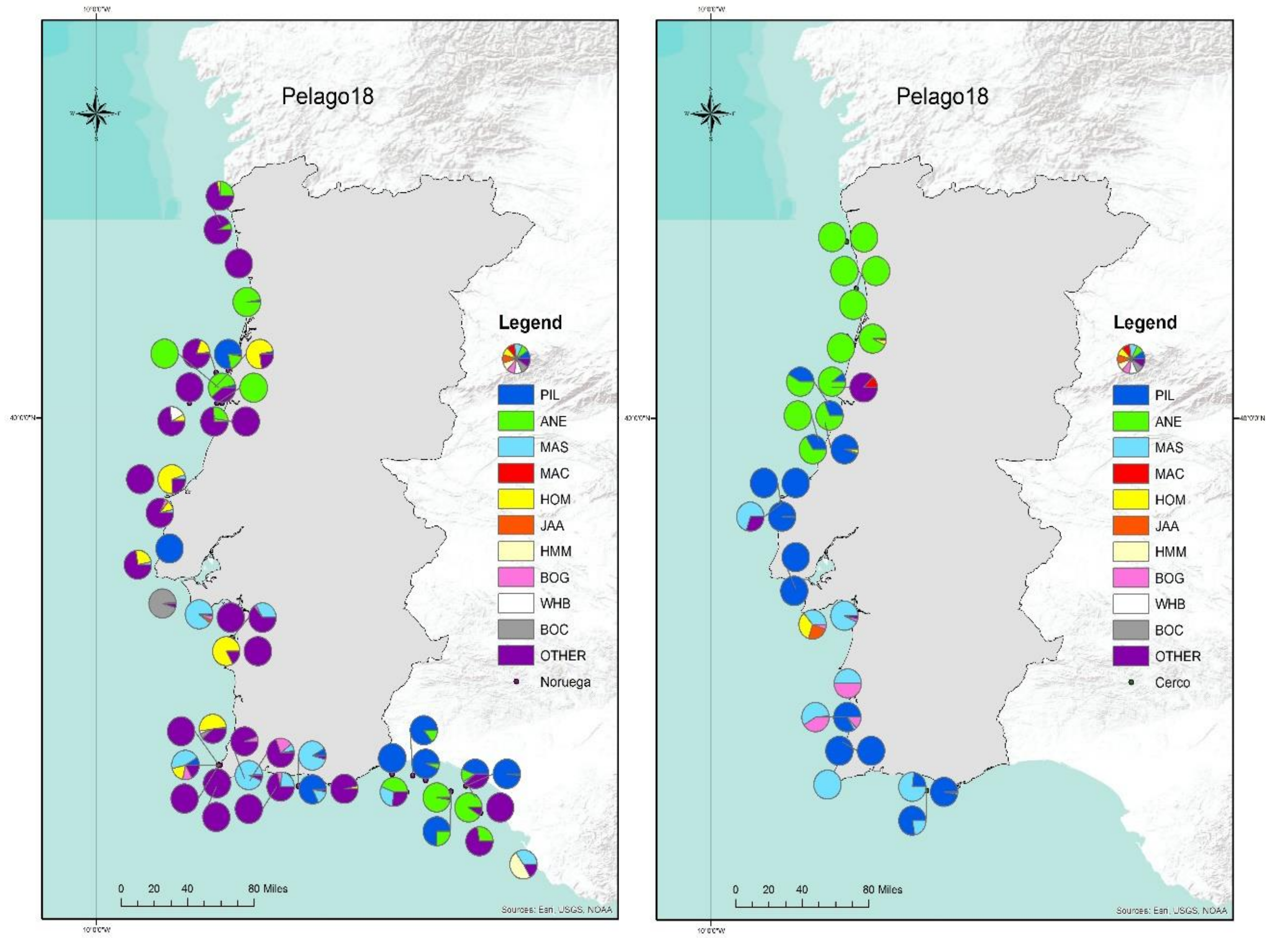


Figure 2.1 – Proportion, in number, of the species caught in the fishing stations. Pelagic and bottom trawl by RV Noruega on the left and the purse-seiners on the right. (PIL-sardine, ANE-anchovy, BOG- bogue, HOM-horse mackerel, MAC-mackerel, MAS-chub mackerel, WHB- blue whiting, JAA- blue jack mackerel, SNS- snipe fish, BOC- boar fish).

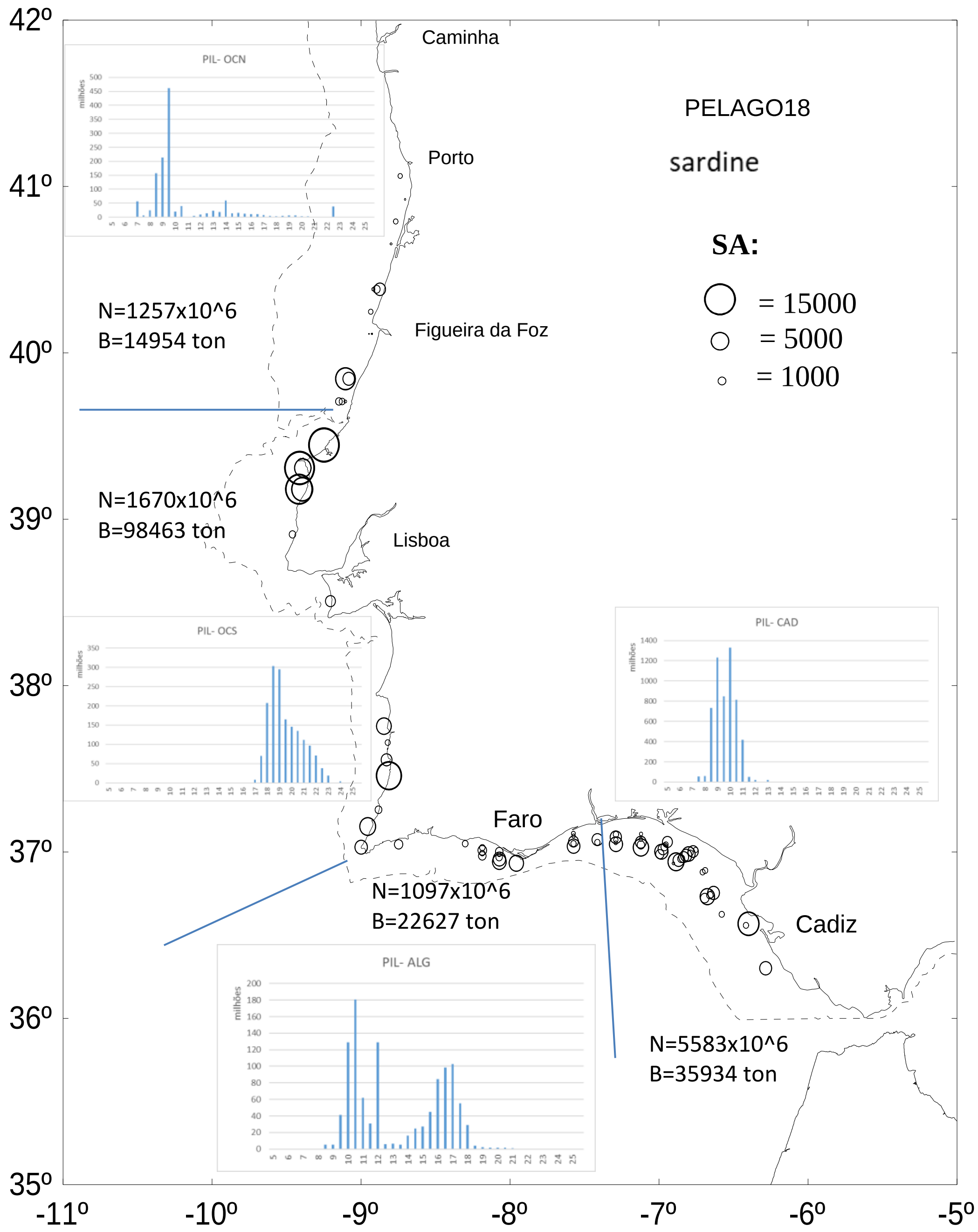


Figure 2.2 – Sardine acoustic energy spatial distribution and size distribution. Circle area is proportional to the acoustic energy ($S_A$ m²/nm²).

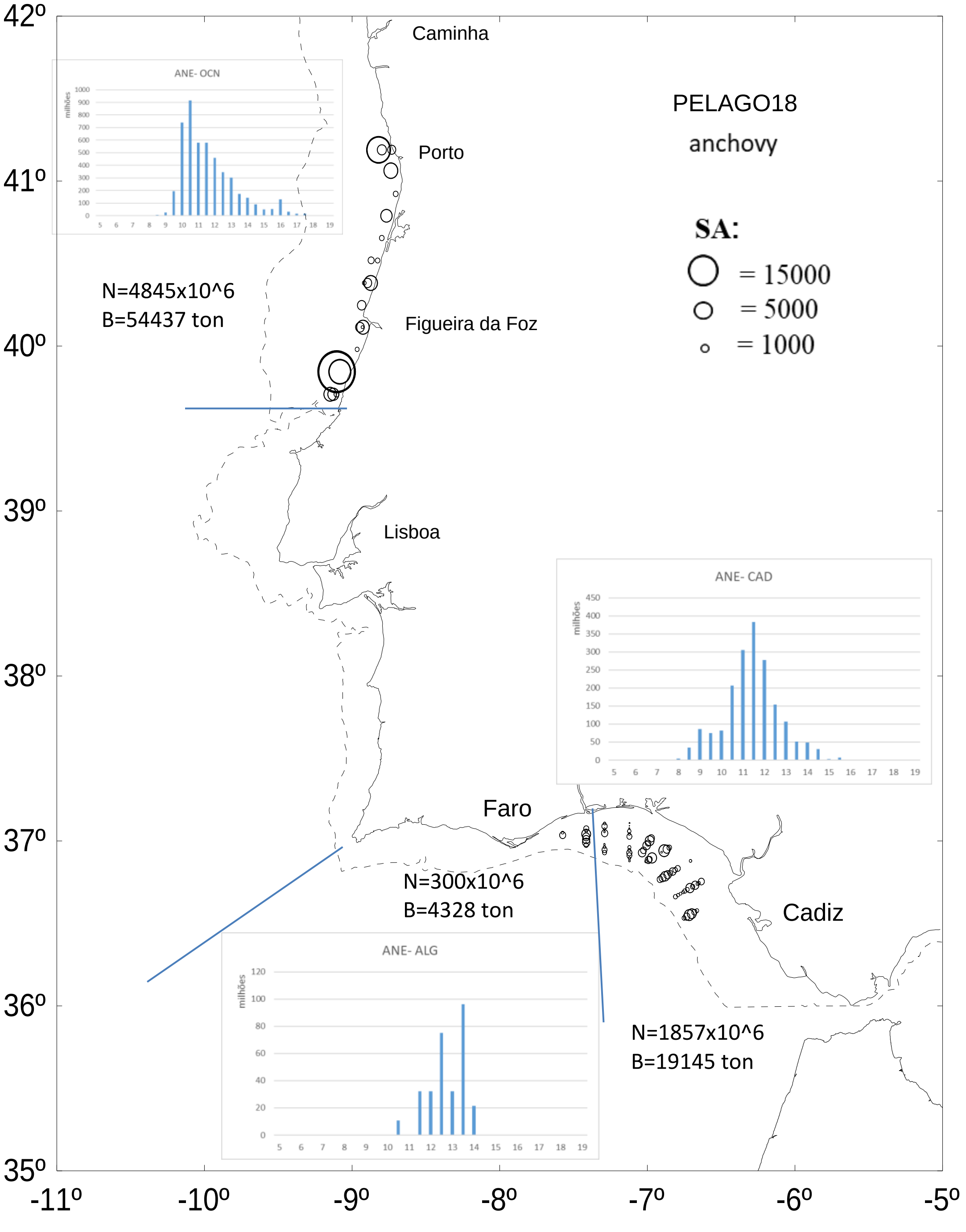


Figure 2.3 – Anchovy acoustic energy spatial distribution and size distribution. Circle area is proportional to the acoustic energy ($S_A$ $m^2/nm^2$).


Figure 2.4 – Sardine abundance (billion fish) and biomass (thousand tonnes) evolution, in each zone, since 2005.

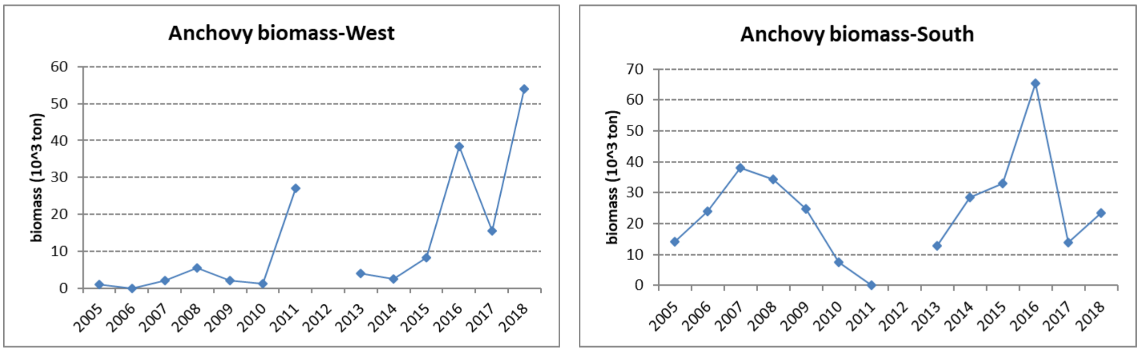


Figure 2.5 - Anchovy biomass (thousand tonnes) evolution off the West Portuguese coast and South (Algarve plus Gulf of Cadiz) coast.

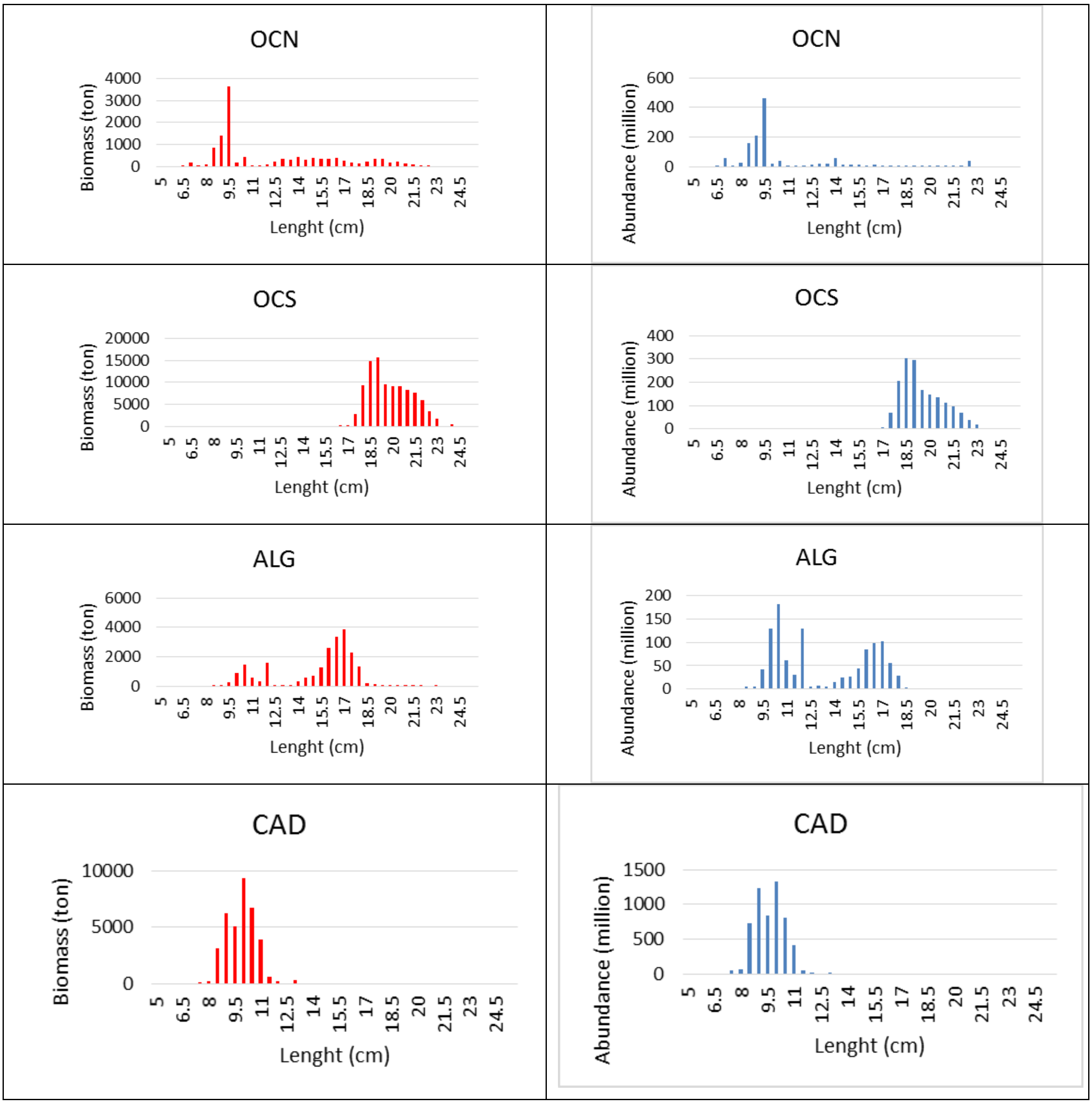


Figure 2.6 – Length composition of sardine biomass and abundance in PELAGO18 survey, by area.

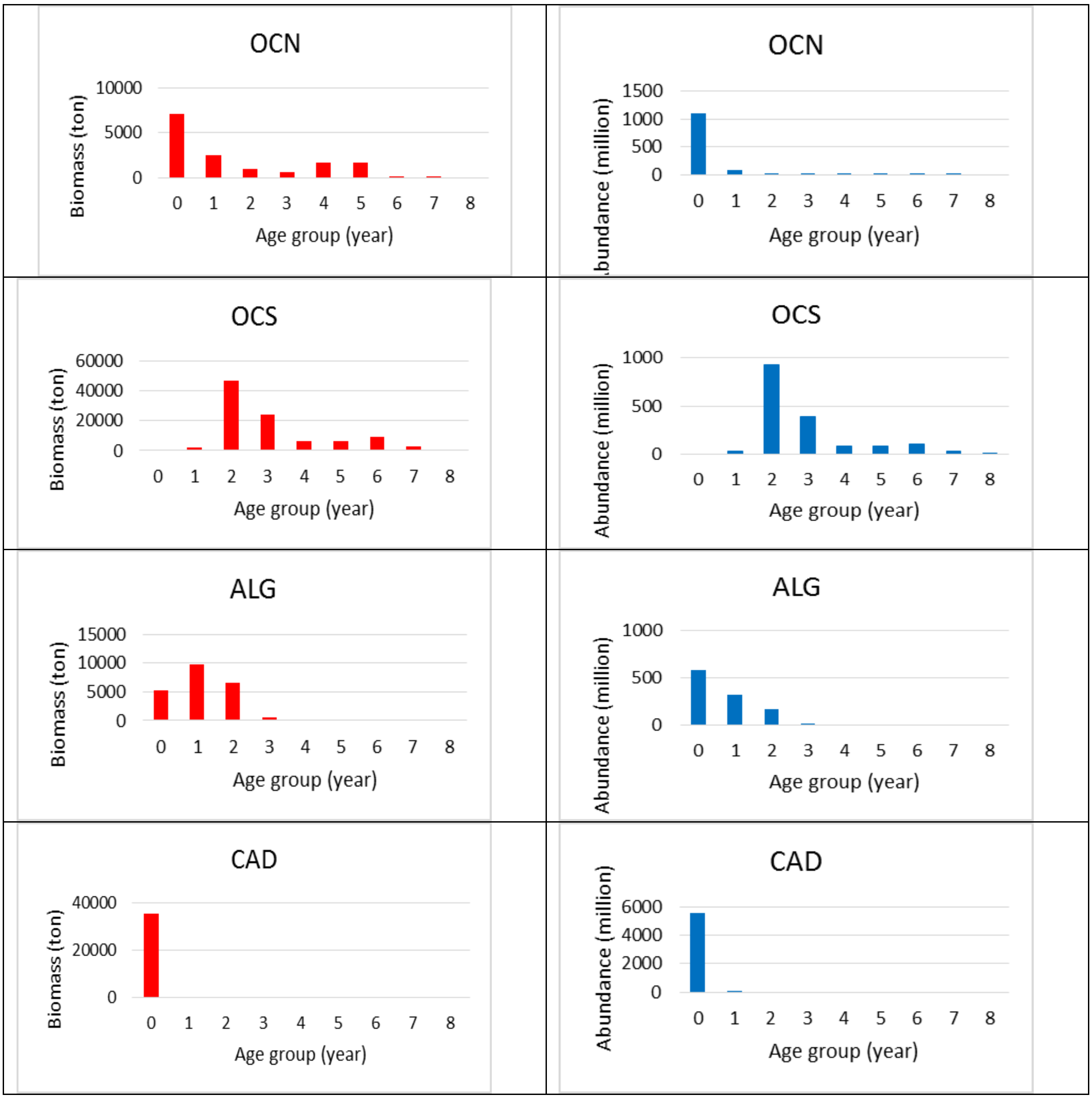


Figure 2.7 – Age distribution of sardine biomass and abundance in PELAGO18 survey, by area.

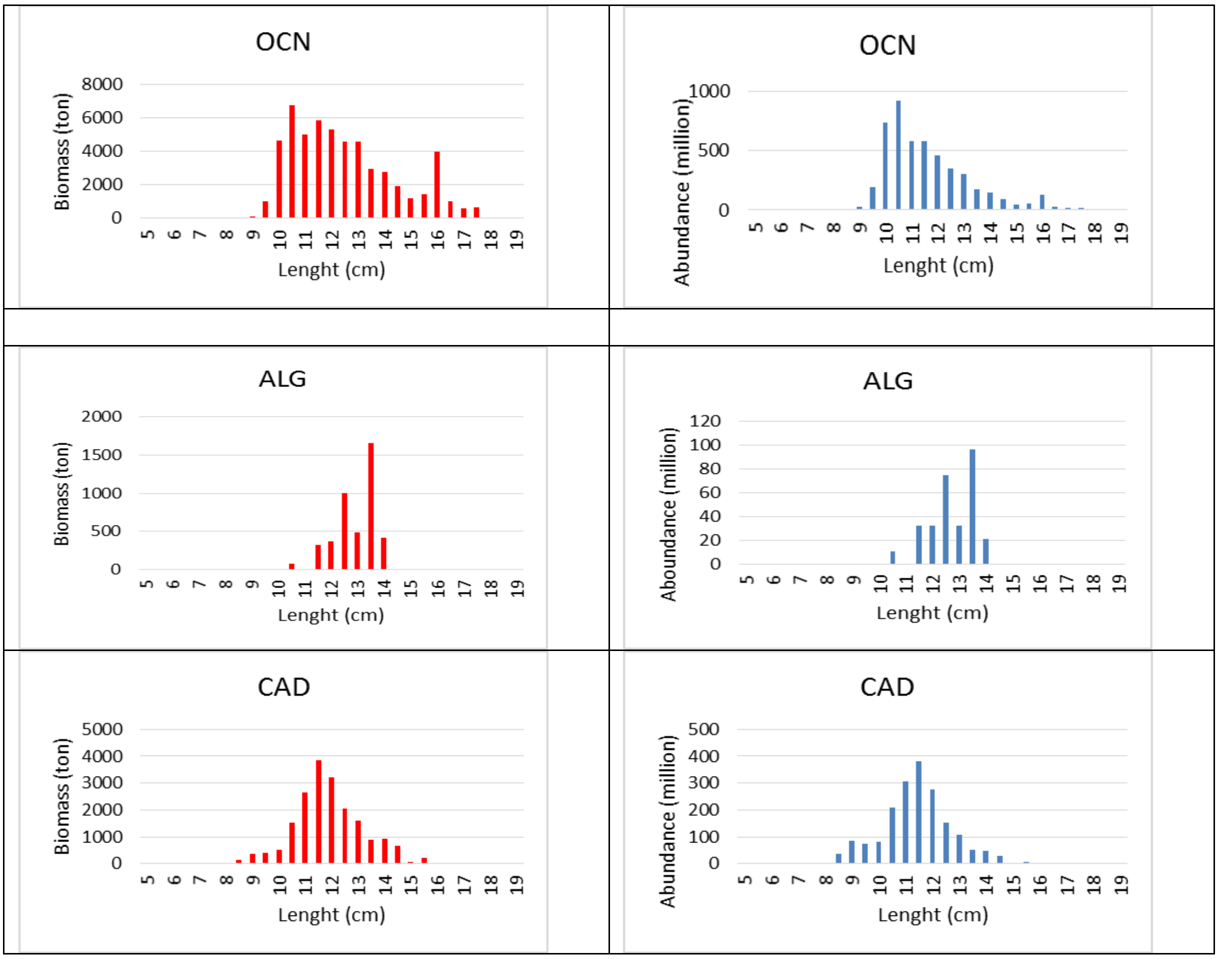


Figure 2.8 – Length composition of anchovy biomass and abundance in PELAGO18 survey, by area.

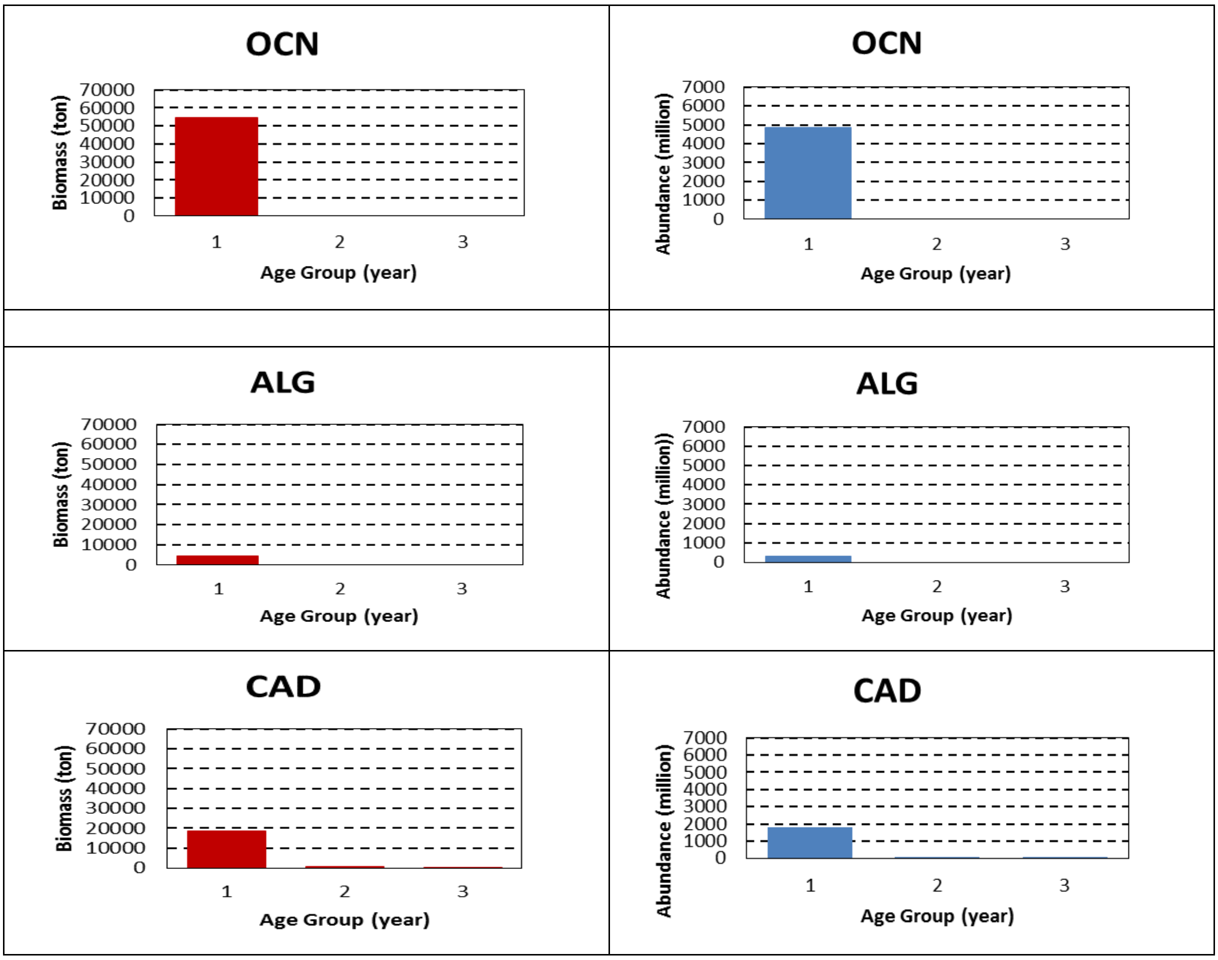


Figure 2.9 – Age distribution of anchovy biomass and abundance in PELAGO18 survey, by area.

## 3. Plankton and environmental surveying

***Material and methods***

*Gear for plankton and hydrology surveying:*

- CUFES: mesh size 335 µm, continuous sampling at the surface (~ 3m)
- BONGO: double nets with 60cm mouth opening (mesh size: 200, 500µm), oblique tows through the whole water column
- NEUSTON NET: for surface sampling; rectangular frame (75x35cm), mesh size 200 µm
- WP2 NET: vertical sampling, 40cm mouth aperture, mesh size 200 µm
- continuous surface observations of temperature, salinity and fluorescence using onboard sensors associated to the CUFES system
- temperature, salinity and fluorescence (chlorophyll) profiles using a CTDF probe

During the day along the acoustics transects regular CUFES (continuously, and collected every 3 miles) surveying was undertaken for zooplankton (ichthyoplankton) sampling. During the night period, when acoustics surveying was not running, sampling of opportunity was conducted, along some of the transects, using the various plankton nets for different zooplankton size fractions and depth strata. Surface, temperature, salinity and fluorescence observations were gathered continuously with the sensors associated to the CUFES system during the day and CTDF profiles were conducted together with the nigh plankton surveying.

***Results***

***Temperature, salinity and fluorescence (chlorophyll$_a$) distributions***

The surface temperature and salinity distribution patterns observed during the PELAGO18 survey were typical for the region, with higher temperatures and salinities on the south coast, progressively lowering towards the west and then, over the western shelf, decreasing from south to north. The values recorded for the water temperature in 2018 were lower than those observed in previous surveys carried out at during the same period. In fact, in 2018 the campaign took place after a few weeks of severe weather, during March and April, when heavy rain and low atmospheric temperatures were observed. March 2018 was the 2nd rainiest March since the 30s (almost identical to 2001) and the coldest of this century and the month of April was also wetter than the average, having had low temperatures during the first half and towards the end of the month (source: IPMA). In accordance with the meteorological scenario, low surface water temperatures were observed during the first leg of the survey (~12.5-13.5°C) on the NW shelf and in particular to the north of Cape Mondego. By the end of May, when the survey was being completed, the temperatures observed to the east of Cape St Maria, were already much higher (~17-20°C) and within the usual values for this zone in late spring. The highest values of fluorescence (proxy for chlorophyll concentration) were observed in the NW zone, associated to the river plumes, between Mondego and

Douro, and in the zone between Cape Mondego and Cape Raso, in connection with the cooler coastal waters upwelled as a consequence of the N-NW wind forcing.

***Fish Egg distribution***

Zooplankton samples were collected with the CUFES system as standard routine during acoustics surveying, a summary of the information gathered is presented in Table 1.1.

A total of 534 CUFES samples were collected along the 71 regular transects of the acoustics survey grid (Table 1.1 and figures 3.2 and 3.3). The truly remarkable feature of the PELAGO18 fish egg survey was the large increase in the anchovy egg abundances (the highest density in the time series) which were observed particularly in the NW region. In total, nearly 160000 anchovy eggs were collected in 74% of the CUFES samples and represented 71% of the total eggs sorted. In the NW 75% of the eggs observed were anchovy eggs (figure 3.3). Sardine egg abundances were higher than during the PELAGO17 however, much lower than the anchovy egg densities (figures 3.2, 3.3 and 3.4) and representing only 8% of the total eggs collected. Sardine eggs were present in nearly half of the CUFES samples (49%) and were mainly observed in the northern region, to the north of river Douro (~43%), but also in a spot south of Cape Carvoeiro.
The high densities of anchovy eggs corresponded well to the anchovy schools (and considerable increase in biomass) detected by the echosounder in the NW and Cadiz Bay (figures 2.3 and 3.3) whereas for sardine there was a match between eggs and adult off Promontório da Estremadura but not in the main patch of eggs, in the northern region, where no acoustic energy was attributed to sardine. The delay in the survey period can explain to some extent the higher anchovy egg abundances and the lower sardine egg densities since the spawning period for sardine was close to its end while for anchovy it was near to its peak. Coincidentally clupeiform larvae abundance spots (figure 3.5) were observed in the same regions were the higher sardine egg abundances were registered. Apart from the plankton sampling undertaken with the CUFES system, during the night period, when acoustics was not running, transects for plankton and temperature, salinity and fluorescence profiles were undertaken. Figures 3.6. and 3.7 show the transects completed during the night sampling and the plankton volumes obtained with the Bongo (mesh sizes 200µm and 500 µm) and neuston nets (mesh size 200µm). The volumes of plankton collected were generally higher for the west coast and with the 200µm meshes higher for the surface hauls compared to the water column trawling (integration from 50m upwards).

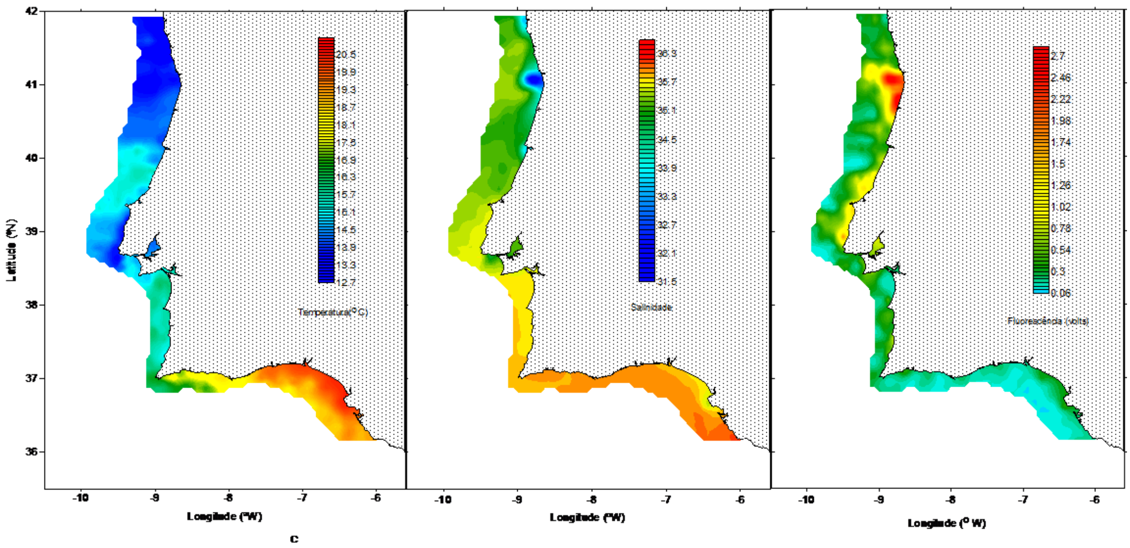


Figure 3.1 – Distributions of surface, temperature (left panel), salinity (central panel) and fluorescence (right panel).

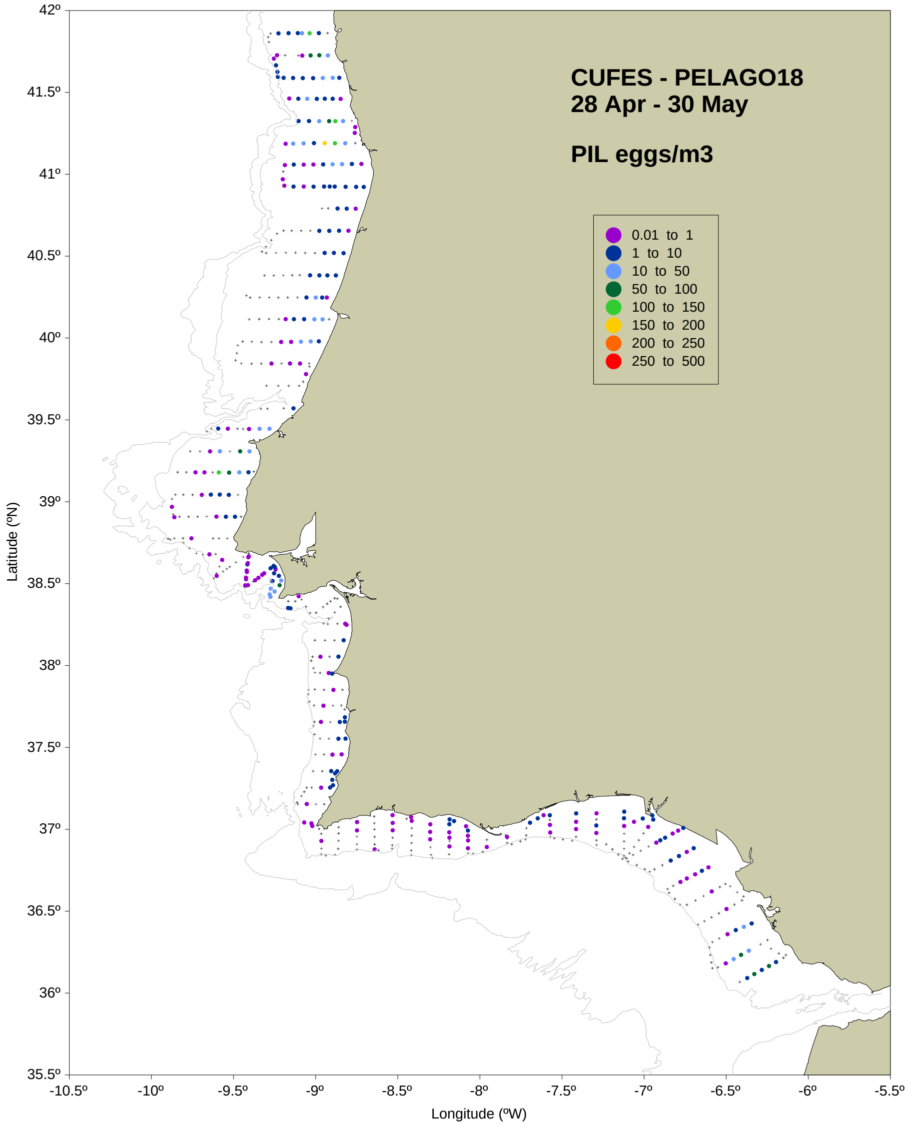


Figure 3.2 - Sardine egg abundance distribution (eggs/m$^2$) obtained from CUFES samples.

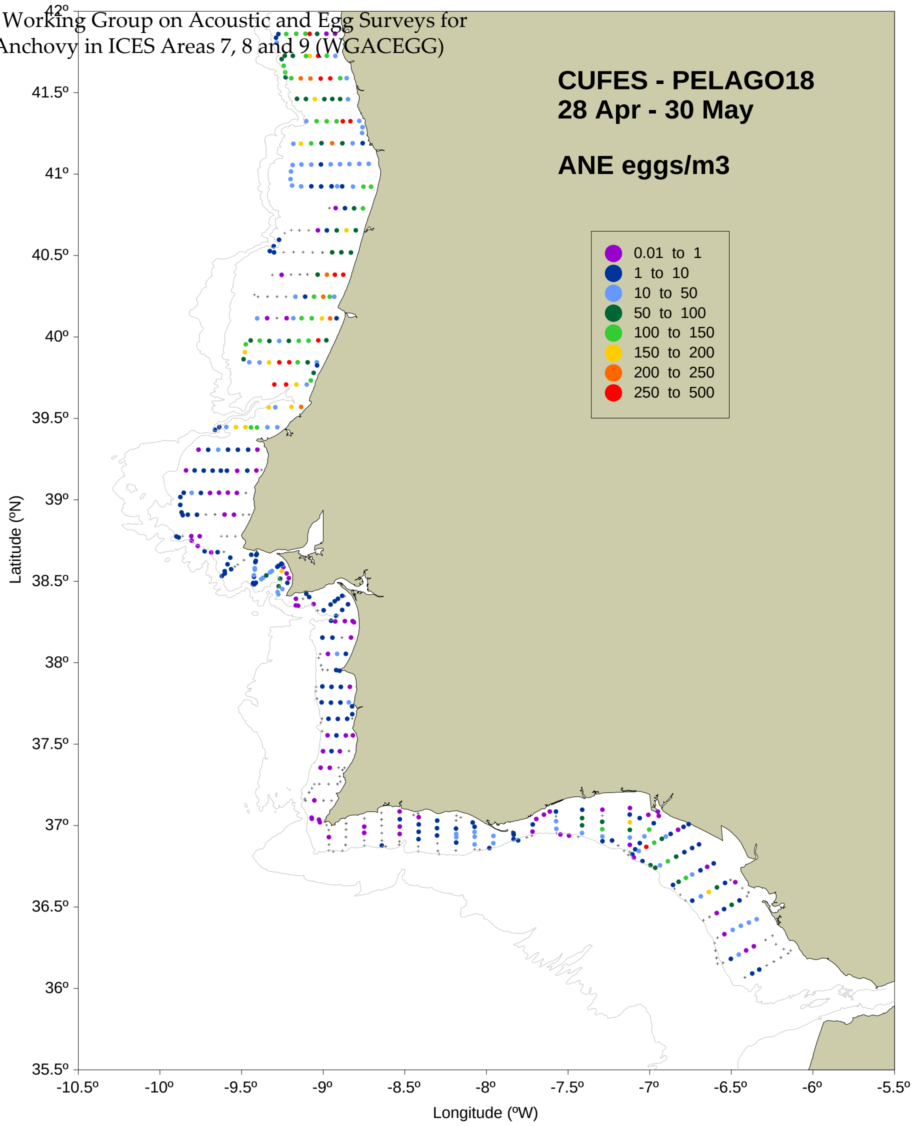


Figure 3.3. Anchovy egg abundance distribution (eggs/m$^2$) obtained from CUFES samples.

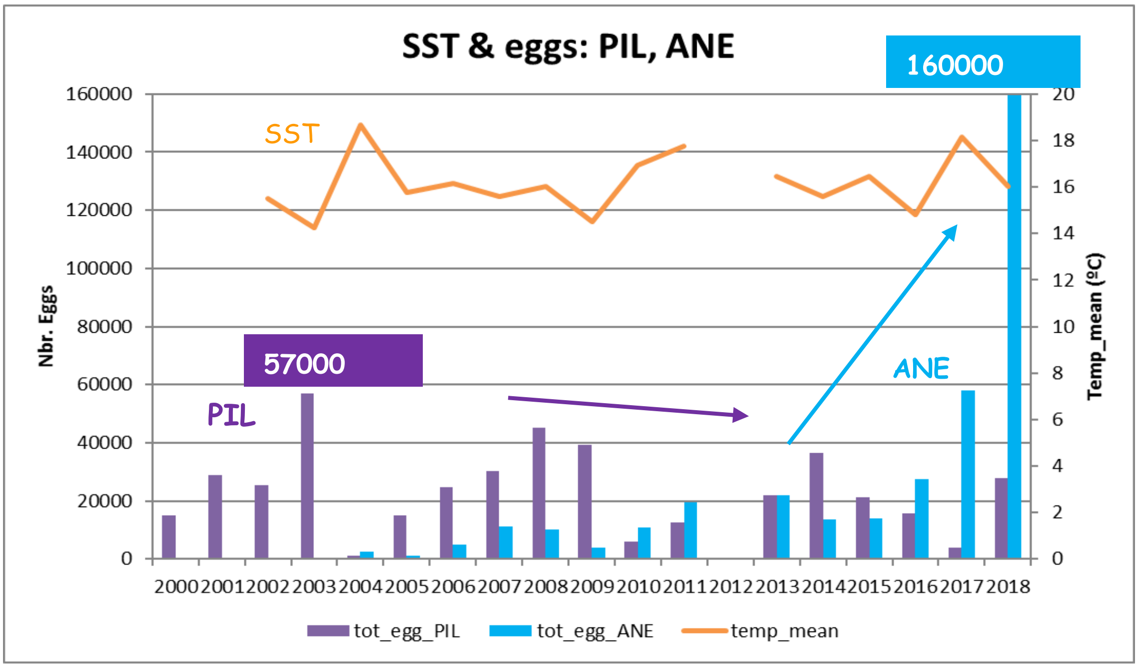


Figure 3.4. Sardine and anchovy total egg abundance in the CUFES samples during the PELAGO series (2000-2018). The orange curve represents mean surface temperature during the surveys in each year.

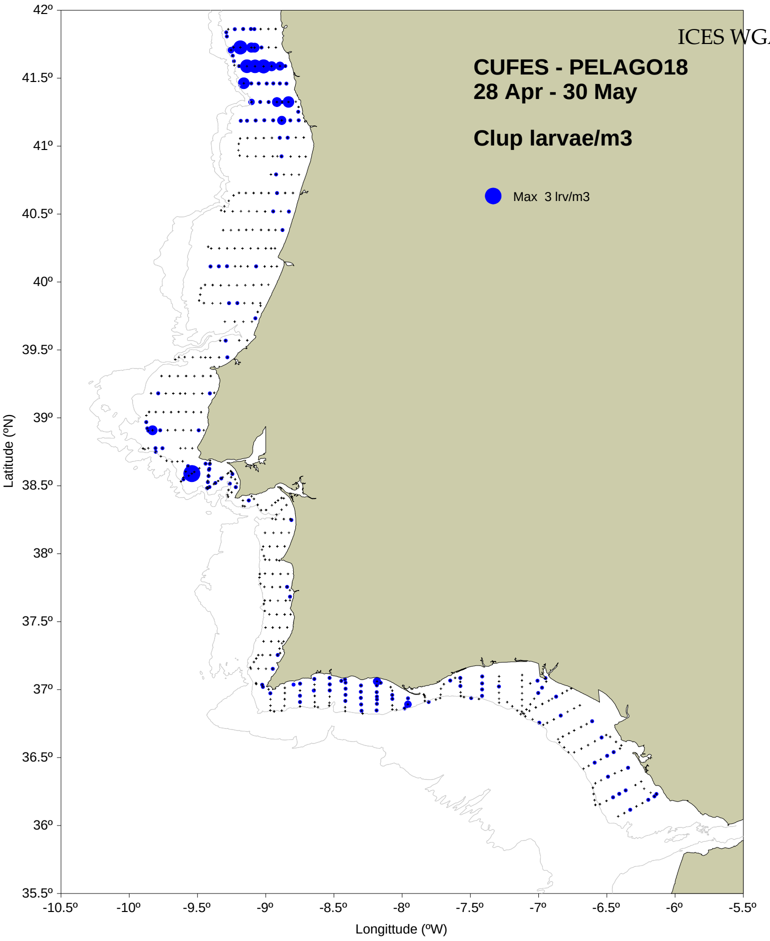


Figure 3.5. Clupeiform larvae distribution (lrv/m$^3$) obtained from CUFES samples.

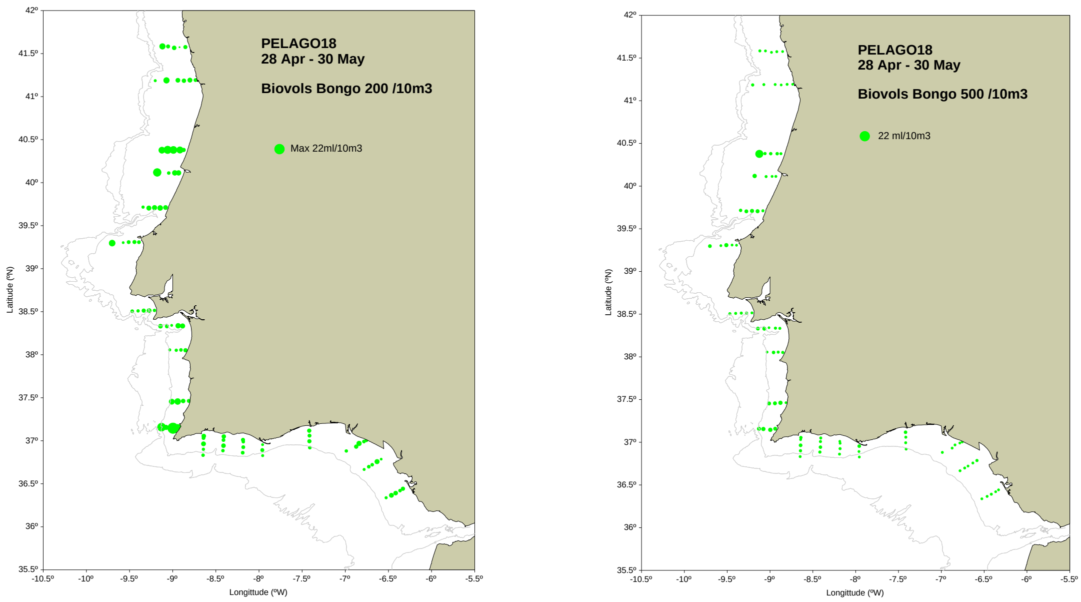


Figure 3.6. Plankton volumes (ml/ 10m$^3$), integration of the water column from 50m upwards, obtained with the Bongo sampler (60cm mouth opening) fitted with a 200 µm mesh size net (left panel), and with a 500 µm mesh size net (right panel).

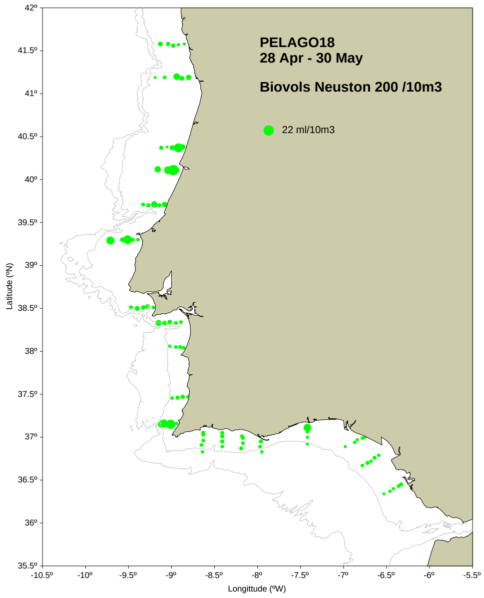


Figure 3.7. Plankton volumes (ml/ 10m$^3$ ) obtained at the surface with a Neuston net (200 µm).

**4. Census of birds and mammals, short summary**

Census for birds and mammals were conducted according to the standard ESAS methodology (*European Seabirds at Sea;* Tasker *et al.* 1984) during the second leg of the survey (during the first half of the survey no observer was onboard). The summary here presented includes 4 groups: (1) The northern gannet (*Morus bassanus*, the most common bird species of this census), (2) the total number of birds, (3) the common dolphin (*Delphinus delphis*, the most abundant mammal of this census) and (4) the total number of marine mammals.

Seabirds were observed in all transects carried out, with the largest number of birds being counted between Lisbon and Setúbal. *Morus bassanus* was observed in practically the whole studied area, with higher densities in the zone of Sines and Portimão. Mammals, mostly common dolphins, were observed between Cape Sardão (south of Sines) and Lagos (Table 4.1 and figures 4.1 and 4.2).

Table 4.1. Mean densities (indiv/km$^2$) and total individuals observed for the 4 groups defined: gannets, total birds, common dolphin and total mammals

| | Mean | SD | Max | Min | Total |
|---|---|---|---|---|---|
| **Gannets** | 1.13 | 2.97 | 29.70 | 0 | 281 |
| **Total birds** | 3.00 | 16.22 | 247.50 | 0 | 727 |
| **Common dolphin** | 0.26 | 2.28 | 32.88 | 0 | 79 |
| **Total mamals** | 0.29 | 2.31 | 32.88 | 0 | 87 |

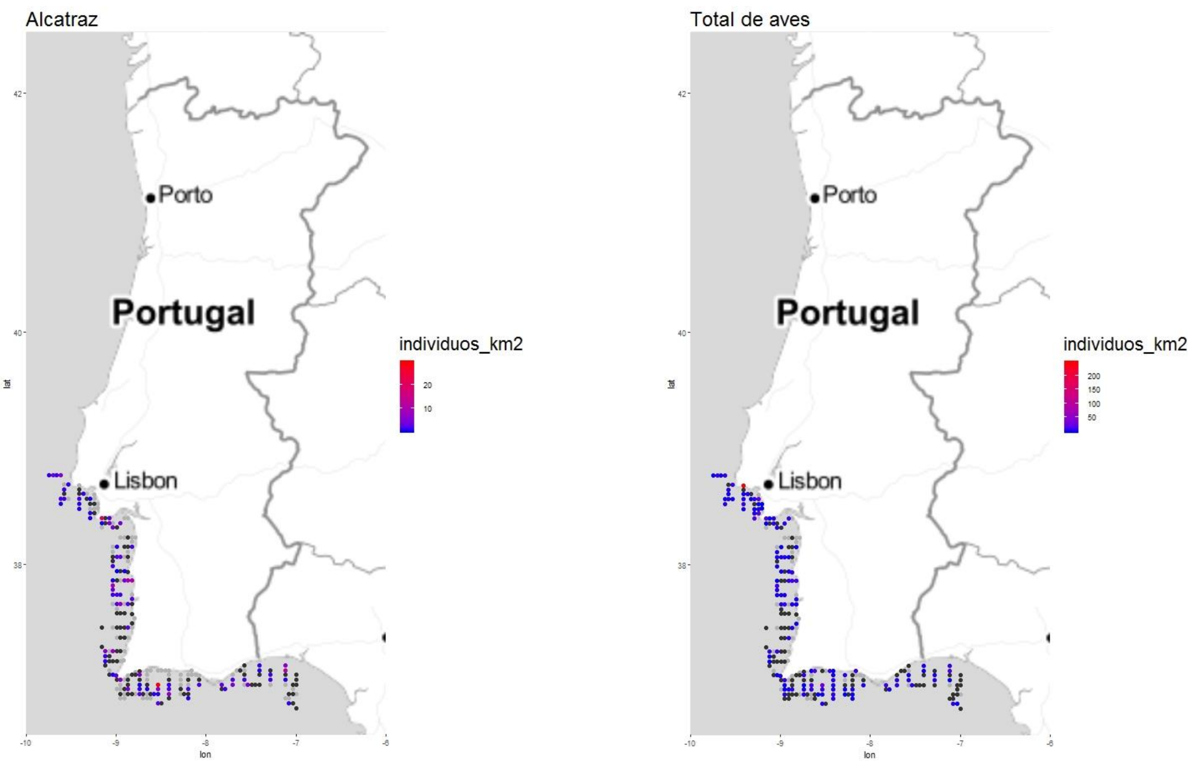


Figure 4.1. Distribution and abundance of gannets (left panel) and total birds (right panel).

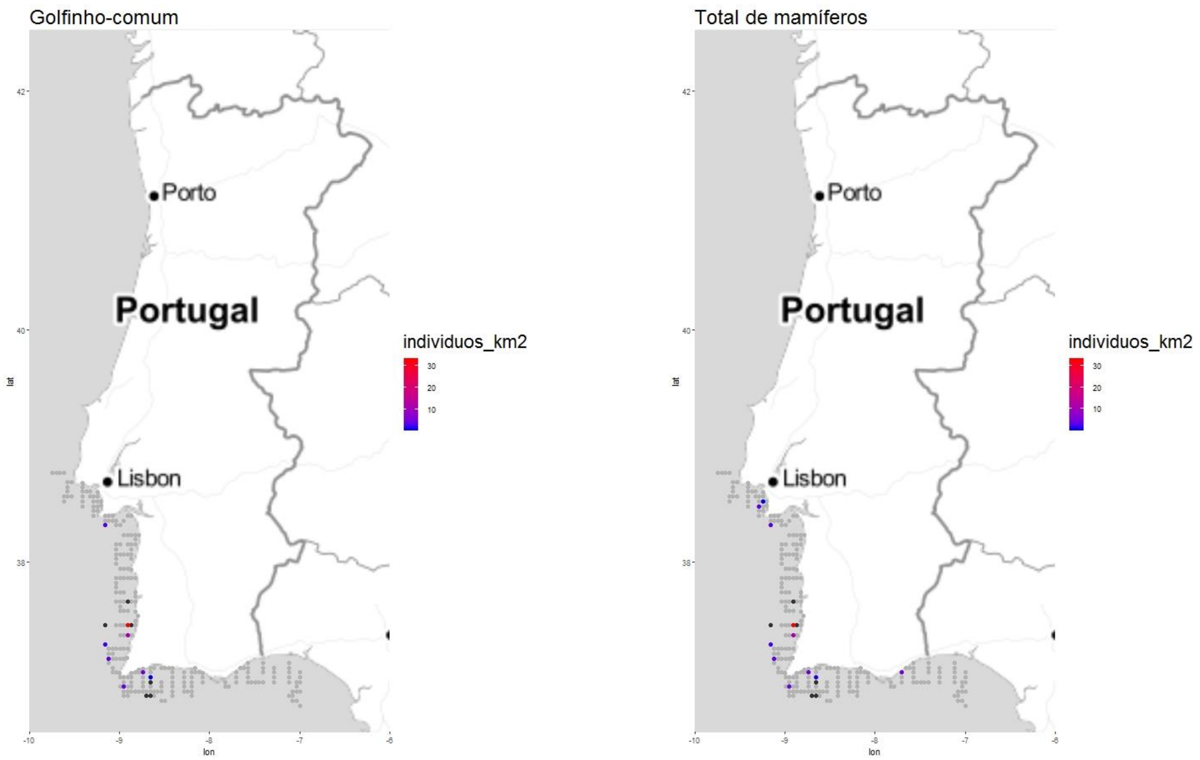


Figure 4.2. Distribution and abundance of common dolphins (left panel) and total mammals (right panel).

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## Annex 3.4: Direct assessment of small pelagic fish by the PELGAS18 acoustic survey

*Please see report on next page.*

*Working Document for* ***WGACEGG***
*Nantes, 19-23 november 2018*

# Direct assessment of small pelagic fish by the PELGAS18 acoustic survey

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# 1. MATERIAL AND METHOD

## 1.1. PELGAS survey on board Thalassa

An acoustic survey (PELGAS) is carried out every year in the Bay of Biscay in spring onboard the French research vessel Thalassa. The objective of PELGAS survey is to study the abundance and distribution of pelagic fish in the Bay of Biscay. The main target species are anchovy and sardine but they are considered in a multi-specific context and within an ecosystemic approach as they are located in the centre of pelagic ecosystem.

This survey is connected with IFREMER programs on data collection for monitoring and management of fisheries and ecosystemic approach for fisheries. This task is formally included in the first priorities defined by the Commission regulation EU N° 199/2008 of 06 November 2008 establishing the minimum and extended Community programmes for the collection of data in the fisheries sector and laying down detailed rules for the application of Council Regulation (EC) No 1543/2000. This survey must be considered in the frame of the Ifremer fisheries ecology action "resources variability" which is the French contribution to the international Globec programme. It is planned with Spain and Portugal in order to have most of the potential area covered from Gibraltar to Brest with the same protocol regarding sampling strategy. Data are available for the ICES working groups WGHANSA, WGWIDE and WGACEGG.

In the spirit of the ecosystemic approach, the pelagic ecosystem is characterised at each trophic level. To achieve this and to assess an optimum horizontal and vertical description of the area, two types of actions are combined:

- Continuous acquisition of acoustic data with two different echosounders, pumping sea-water under the surface in order to evaluate the number of fish eggs using a CUFES system (Continuous Under-water Fish Eggs Sampler) and a visual counting and identification of cetaceans and birds (from board) carried out in order to characterise the higher level predators of the pelagic ecosystem.
- Discrete sampling at stations (by pelagic trawls, plankton nets, CTD).

Satellite imagery (temperature and sea colour) and modelling have been also used before and during the survey to recognise the main physical and biological structures and to improve the sampling strategy.

The strategy this year was the identical to previous surveys (2000 to 2016). The survey protocols are described *in Doray M, Badts V, Masse J, Duhamel E, Huret M, Doremus G, Petitgas P (2014).* ***Manual of fisheries survey protocols. PELGAS surveys (PELagiques GAScogne)***. *http://dx.doi.org/10.13155/30259:*

Biomass and abundance at length of small pelagic fish during the PELGAS survey has been published in SEANOE: *.Doray Mathieu, Duhamel Erwan, Sanchez Florence, Grellier Patrick, Pennors Laurence, Petitgas Pierre (2018). Biomass and abundance at length of small pelagic fish estimated during the PELGAS survey in the Bay of Biscay in springtime . SEANOE .* http://doi.org/10.17882/53388

- acoustic data were collected along systematic parallel transects perpendicular to the French coast (figure 1.1.1). The length of the ESDU (Elementary Sampling Distance Unit) was 1 nautical mile and the transects were uniformly spaced by 12 nautical miles and cover the continental shelf from 20 m depth to the shelf break (or sometimes more offshore ï see figure below).

- acoustic data were only collected during the day because of pelagic fishes behaviour in this area. These species are usually dispersed very close to the surface during the night and so "disappear" in the blind layer of the echo-sounders between the surface and 8 m depth.

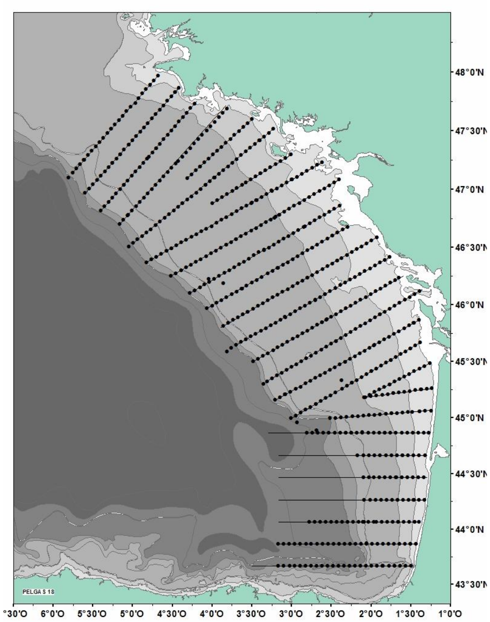



**Fig. 1.1.1** - Transects prospected during PELGAS18 by Thalassa.

In 2018, as in previous surveys (since 2009), three modes of acoustic observations were used:

- 1 SIMRAD ME70 multi-beam echo-sounder (21 2 to 7°beams, from 70 to 120 kHz) used essentially for visualisation and observing the behaviour and shapes of fish schools during the whole survey. Nevertheless, only echoes stored on the vertical echo-sounder were used for abundance index calculation.
- 1 horizontal echo-sounder on the starboard side for surface echo-traces
- this year, the broadband echosounder EK80 was installed and used

Energies and samples provided by all sounders were simultaneously visualised and stored using the MOVIES3D software and stored at the same standard HAC format.

The calibration method was the same that the one described for the previous years (see WD 2001) and was performed at anchorage near Brest, in the West of Brittany, in good meteorological conditions at the beginning of the survey.

Acoustic data were collected by R/V Thalassa along a total amount of 4836 nautical miles from which 1882 nautical miles on one way transect were used for assessment. A total of 30 077 fishes were measured (including 9752 anchovies and 6507 sardines) and 3 426 otoliths were collected for age determination (1 908 of anchovy and 1 518 of sardine).

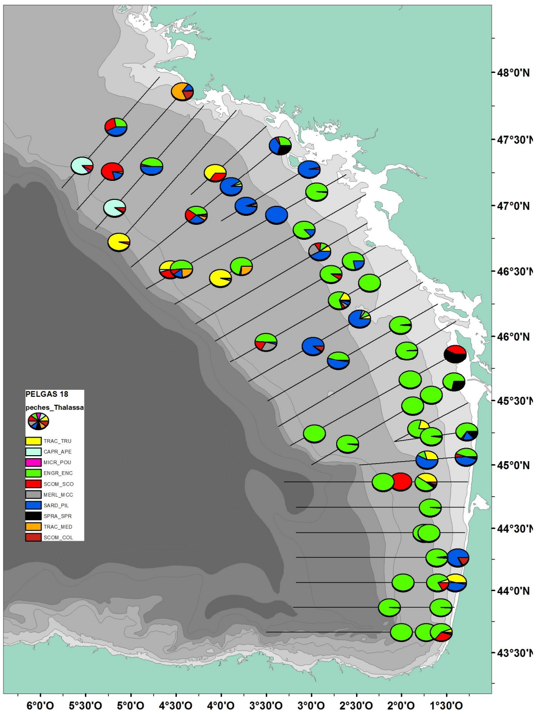



**Fig. 1.1.2:** Species distribution according to Thalassa identification hauls.

## 1.2. The consort survey

A consort survey is routinely organised since 2007 with French commercial vessels during 17 days. This approach is in identical to last yearꞌs surveys, using the commercial vesselꞌs hauls were for echoes identification and biological parameters to complement hauls made by the R/V Thalassa.

Four commercial vessels (two pairs of pelagic trawlers) participated to PELGAS18 survey:

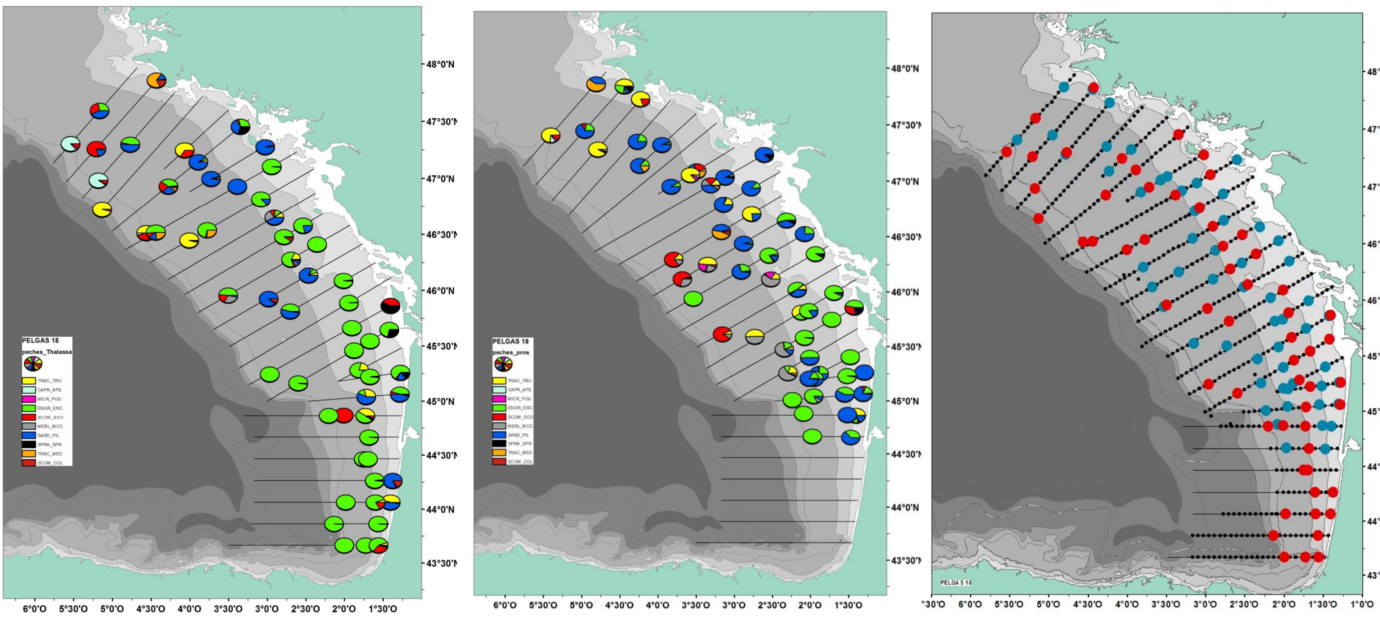
| Vessel | Gear | Period | Days at sea |
|---|---|---|---|
| Cintharth / Marilude | Pelagic pair trawl | 05/05 to 13/05/2018 | 9 |
| Papi Paul / Joker | Pelagic pair trawl | 16/05 to 23/05/2018 | 8 |

The regular transects network agreed for several years for Thalassa is 12 miles separated in parallel transects. Commercial vessels worked between standard transects and 2 NM northern. Sometimes, they carried out fishing operations on request. Their pelagic trawl was up to 25 m vertical opening and the mesh of their codend was similar to the on uses by the R/V Thalassa (12 mm).

A scientific observer was on board the commercial vessel to control every fishing operation, and to collect biological data. The fishing operations were systematically agreed after a radio contact with Thalassa in order to confirm their usefulness. In some occasions, these fishing operation were used to check the spatial extension of species already observed and identified by Thalassa (and therefore the spatial distribution); in others the objective was to enlarge the vertical distribution description by stratified catches. Globally, a great attention was given on a good distribution of samples to avoid over-sampling on some situations. Regularly a biological sample was provided by the commercial vessels to Thalassa to improve otoliths collection and sexual maturity (200 otoliths of anchovy, 420 of sardine). A total of 11 518 fishes were measured onboard commercial vessels, including 3 053 anchovies and 3 049 sardines.

Catches and biological data were used to complement the sampling made on board the R/V Thalassa.

A total of 121 hauls (including 5 not valid) were carried out during the consort survey including 60 hauls by the R/V Thalassa and 61 hauls by commercial vessels.



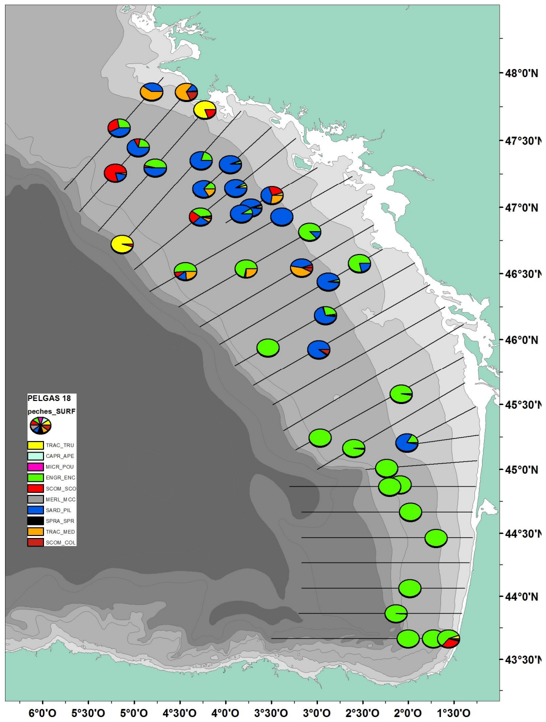

*a) Thalassa (nb :60)* *b) Commercial vessels (nb : 61)* *c) all fishing hauls (nb :121) Thalassa in red and commercial in blue*

**Figure 1.2.2 :** fishing operations carried out by Thalassa and commercial vessels during consort survey PELGAS18

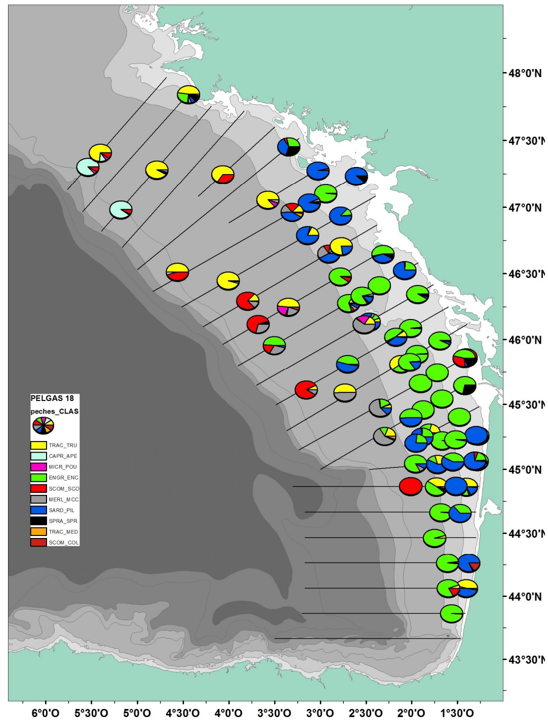
The collaboration between Thalassa and commercial vessels was excellent. It was once more a very good opportunity to 1)explain our methodology to the fishermen and 2) check consistency between scientists and fishermen echo-traceôs observation and interpretations. Some fishing operations were done in parallel by Thalassa and commercial vessel in order to check catchesô similarity (in proportion of species and, most of the time, in quantity as well - taking the vertical and horizontal opening into account). As last year, commercial vesselsô fishing operations were only carried out at day time (as for Thalassa) each time it was necessary.

**Table 1.2.3. :** Number of fishing operations carried out by Thalassa and commercial vessels during consort survey PELGAS18

| | thalassa | commercial | total |
|---|---|---|---|
| classic | 35 | 41 | 76 |
| surface | 24 | 16 | 40 |
| null | 1 | 4 | 5 |
| total | 60 | 61 | 121 |




a) Hauls carried out at surface or in mid-water levels (Thalassa & commercial vessels)




b) classic Hauls carried out near the bottom and 50m upper (Thalassa + commercial vessels)

**Figure 1.2.4 :** Vertical localisation of fishing operations carried out by Thalassa and commercial vessels and species composition during PELGAS18 survey

# 2. ACOUSTICS DATA PROCESSING

## 2.1. Echo-traces classification

All the acoustic data along the transects were processed and scrutinised by the date of the meeting. Acoustic energies (Sa) have been cleaned by sorting only fish energies (excluding bottom echoes, parasites, plankton, etc.) and classified into 6 categories of echo-traces this year:

D1 ï energies attributed to mackerel, chub mackerel, horse mackerel, Mediterranean horse mackerel blue whiting, hake, corresponding to cloudy schools or layers (sometimes small dispersed points) close to the bottom or of small drops in a 10m height layer close to the bottom.

D2 ï energies attributed to anchovy, sardine, and sprat corresponding to the usual echo-traces observed in this area since more than 15 years, constituted by schools well defined, mainly situated between the bottom and 50 meters above. These echoes are typical of clupeids in coastal and sometimes more offshore areas.

D3 ï energies attributed to scattered detection corresponding to blue whiting, myctophids, boarfish, mackerel, chub mackerel, horse mackerel, mediterranean horse mackerel, and hake.

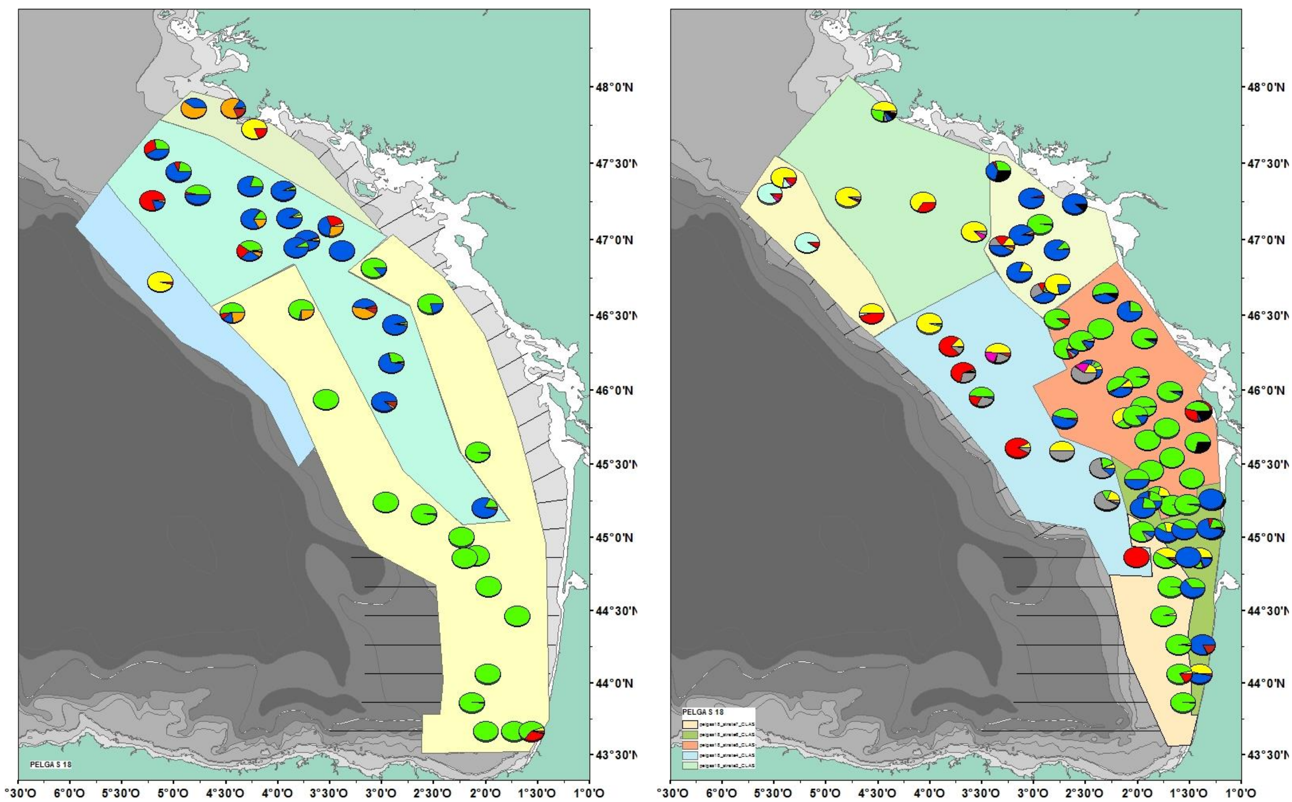
D4 ï energies attributed to sardine, mackerel and anchovy corresponding to echoes very close to the surface. This year, horse mackerel was also allocated in this category

D8 ï energies attributed exclusively to sardine (big and very dense schools).

D9 ï energies attributed exclusively to anchovy.

### 2.2. Splitting of energies into species

As for previous years (except in 2003, see WD-2003), the global area has been split into several strata where coherent communities were observed (species associations) in order to minimise the variability due to different species assemblages. Figure 2.2 shows the strata considered to evaluate biomass of each species. For each stratum, energies where converted into biomass by applying catch ratio, length distributions and weighted by abundance of fish in the haul surrounded area.




Coherent surface strata Coherent classic strata

**Fig. 2.2** ï Coherent strata (classic and surface), in terms of echoes and species distribution, taken into consideration for multi-species biomass estimate from acoustic and catches data during PELGAS18 survey.

### 2.3. Biomass estimates

The fishing strategy has been followed all along the survey in order to benefit of each vesselôs efficiency and maximise the number of samples (in term of identification and biological parameters). Therefore, the commercial vessels carried out mostly surface hauls when Thalassa fished preferably in the bottom layer. According to previous strata (Figure 2.2), using both Thalassa and consort fishing operations, biomass estimates were calculated for each main pelagic species in the surveyed area.

Biomass indices are presented in tables 2.3.1 and 2.3.2 and in figure 2.3.1. No estimate is provided for mackerel according to the low level of TS and particular behaviour in the Bay of Biscay where it is scattered and mixed with plankton echoes.

Anchovy was more abundant than last year and their abundance was estimated this year at a high level compared to the historical time series (around 185 000 tonnes). Strong densities were observed in the Gironde area. It must be noticed that we observed anchovy on every transects from the Spanish coast untill the North West of the Bay on Biscay.

Sardine was less present this year compared to 2017, mainly in coastal waters in the South (where an upwelling occured) and it was also present in variable densities in surface or close to the bottom on the shelfbreak in the North.

Even the densities were not that important, the presence at the surface of a mix sardine/anchovy/horse mackerel on the middle part of the Northern part of the bay (the great mud bank) must be noticeable. Northern than 46°30 N, no sardine or anchovy were detected at the shelfbreak

About other species, another characteristic of this year was that horse mackerel showed a increase of the biomass again, after 3 years of increasing and one of decreasing. The biomass reached again a medium level compared to the abundance calculated in recent years, but far away of the biomasses calculated at the beginning of the serie. Small horse mackerel were detected in the South until the Gironde, and large fishes were present dispersed closed to the surface in the North.

Mackerel appeared abundant this year, particularly in the middle of the bay of Biscay, and scattered close to the bottom in the Northern part.

Blue whiting was more or less absent from the bay of Biscay during Pelgas18

Table 2.3.1. Acoustic biomass index for the main species by strata during PELGAS18

| | **Classic** | **Surface** | **total** |
|---|---|---|---|
| boarfish | 3 378 | | 3 378 |
| **anchovy** | **160 906** | **24 619** | **185 524** |
| hake | 42 797 | 1 256 | 44 053 |
| blue whiting | 2 560 | 941 | 3 501 |
| **sardine** | **240 825** | **24 679** | **265 504** |
| chub mackerel | 62 980 | 2 809 | 65 789 |
| mackerel | 403 564 | 14 990 | 418 555 |
| sprat | 16 321 | | 16 321 |
| mediterranean horse mackerel | 22 739 | 8 752 | 31 491 |
| horse mackerel | 87 717 | 4 042 | 91 759 |

Table 2.3.2. Acoustic biomass index for the five main pelagic species since the beginning of PELGAS surveys (2000)

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **anchovy** | **113 120** | **105 801** | **110 566** | **30 632** | **45 965** | **14 643** | **30 877** | **40 876** | **37 574** | **34 855** | **86 354** | **142 601** | **186 865** | **93 854** | **125 427** | **372 916** | **89 727** | **134 500** | **185 524** |
| *CV anchovy* | *0.064* | *0.141* | *0.113* | *0.132* | *0.167* | *0.171* | *0.136* | *0.100* | *0.162* | *0.112* | *0.147* | *0.0774* | *0.04665* | *0.1282* | *0.062928* | 0.073551 | 0.13 | 0.154339 | 0.0699 |
| **Sardine** | **376 442** | **383 515** | **563 880** | **111 234** | **496 371** | **435 287** | **234 128** | **126 237** | **460 727** | **479 684** | **457 081** | **338 468** | **205 627** | **407 740** | **339 607** | **416 524** | **229 742** | **465 022** | **265 504** |
| *CV sardine* | *0.083* | *0.117* | *0.088* | *0.241* | *0.121* | *0.135* | *0.117* | *0.159* | *0.139* | *0.098* | *0.091* | *0.0699* | *0.07668* | *0.0738* | *0.065212* | 0.102315 | 0.08 | 0.060653 | 0.0620727 |
| **Sprat** | **30 034** | **137 908** | **77 812** | **23 994** | **15 807** | **72 684** | **30 009** | **17 312** | **50 092** | **112 497** | **67 046** | **34 726** | **6 417** | **44 651** | **33 894** | **91 248** | **36 593** | **15 778** | **16 321** |
| *CV sprat* | *0.098* | *0.155* | *0.120* | *0.198* | *0.178* | *0.228* | *0.162* | *0.132* | *0.268* | *0.108* | *0.108* | | | *0.1992* | *0.241009* | 0.19534 | 0.44 | 0.52701 | 0.5879399 |
| **Horse mackere** | **230 530** | **149 053** | **191 258** | **198 528** | **186 046** | **181 448** | **156 300** | **45 098** | **100 406** | **56 593** | **11 662** | **61 237** | **7 435** | **33 471** | **53 154** | **77 142** | **119 230** | **61 919** | **93 728** |
| *CV HM* | *0.079* | *0.204* | *0.156* | *0.137* | *0.287* | *0.160* | *0.316* | *0.065* | *0.455* | *0.09* | *0.188* | | | *0.3007* | *0.227089* | 0.15498 | 0.3 | 0.288318 | 0.1443578 |
| **Blue Whiting** | - | - | **35 518** | **1 953** | **12 267** | **26 099** | **1 766** | **3 545** | **576** | **4 333** | **48 141** | **11 823** | **68 533** | **25 715** | **25 015** | **8 684** | **11 852** | **23 944** | **3 585** |
| *CV BW* | - | - | *0.386* | *0.131* | *0.202* | *0.593* | *0.210* | *0.147* | *0.253* | *0.219* | *0.074* | | | *0.1542* | *0.337606* | *0.223479* | *0.15* | *0.147063* | *0.30485* |

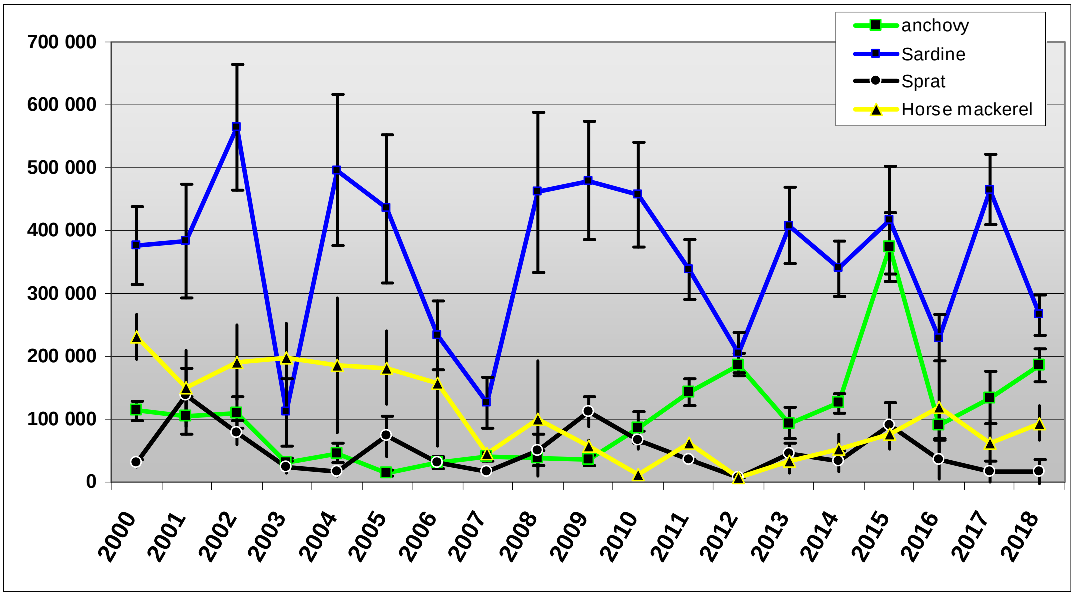



**figure 2.3.3.** ï biomass estimates using Thalassa acoustic data along transects and all the consort identification fishing operations (Thalassa + commercial vessels) and associated coefficients of variation.

# 3. Anchovy data

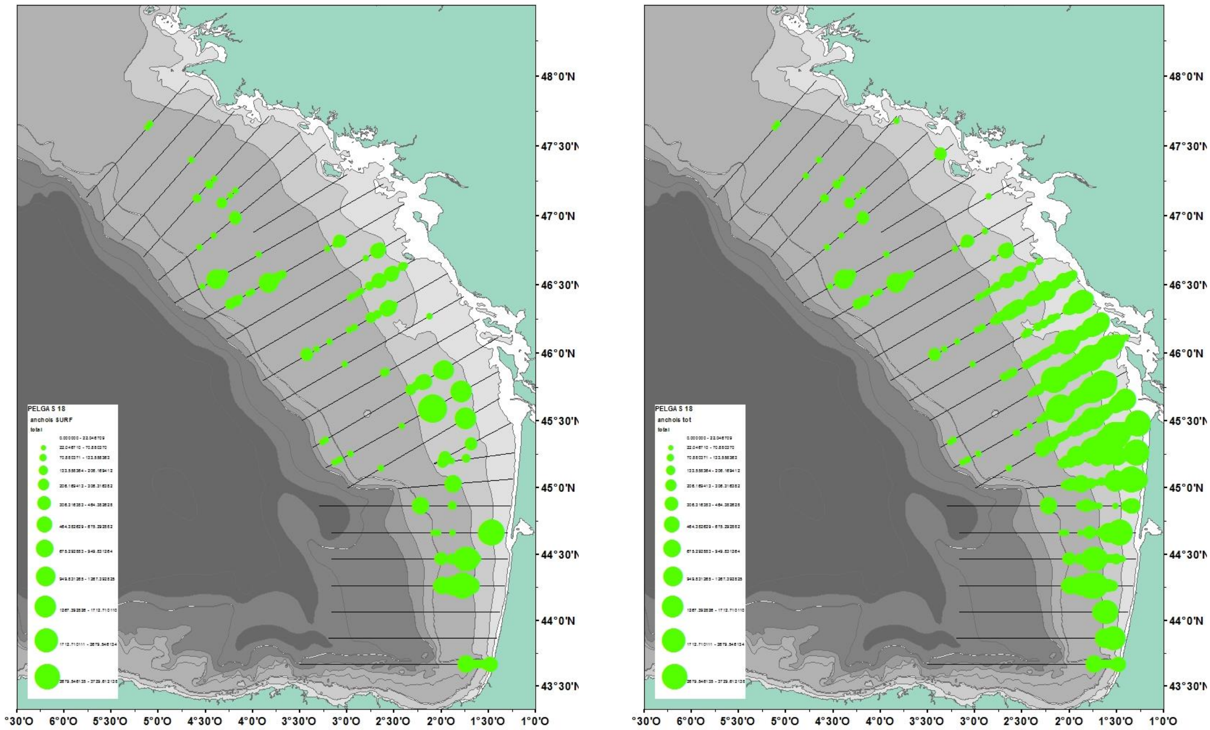
## 3.1. anchovy biomass

The biomass estimate of anchovy observed during PELGAS2018 is **185 500** tons. (table 2.3.2.), which seems to be a (very) high biomass compared to the serie, and comparable to 2012.

In the Gironde area, the configuration was usual in terms of energy compared to what was observed last years, with a high energy attributed to anchovy.

The one year old anchovies were mostly present front of the Gironde (in terms of energy and, as well, biomass) but they were still well present on the platform, till Brittany along the bathymetric line of 100m. The average size of one year old fish was comparable the average size in recent years (two years really differed from the average: 2012 and particularly 2015 where fishes were much smaller) but shows a clear decreasing trend, year after year. bigger (and older) fish appeared close to the surface in the north-West, at the surface on the great mud bank, mixed with sardine

One years old anchovies were also present, in lower quantities, mixed with older fish, even offshore.




Surface distribution Total distribution

**Figure 3.1.** ï Anchovy distribution according to PELGAS18 survey.

## 3.2. Anchovy length structure and maturity

Length distribution in the trawl hauls were estimated from random samples. The population length distributions (figures 3.2) were estimated by a weighted average of the length distribution in the hauls. Weights used are acoustic coefficients (Dev*Xe Moule in thousands of individuals per n.m.$^2$) which correspond to the abundance in the area sampled by each trawl haul.

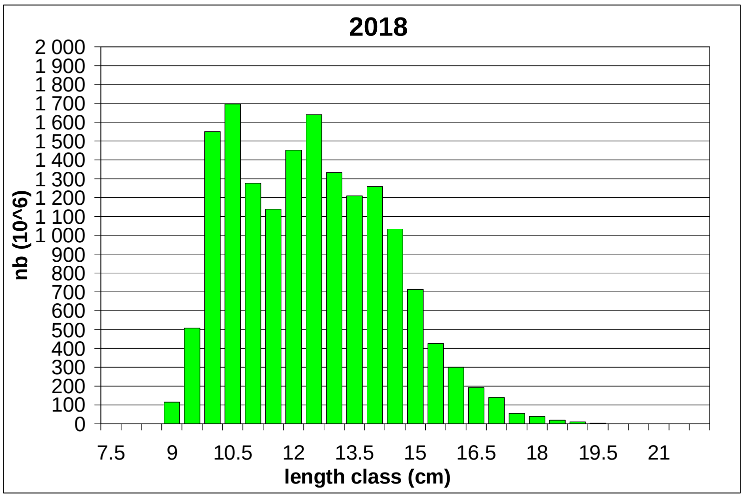



**Figure 3.2**: length distribution of global anchovy as observed during PELGAS18 survey

Globally we observe that length structure shows a classic distribution, with fish from 8 to 18 centimetres. It must be noticed that even if some individuals were small (less than 10 cm), almost all fishes were mature and in their spawning period. This observation on maturity contrasted with the 2015 observation where a large proportion of the population was not spawning at the period of the survey.

## 3.3. Demographic structure

An age length key was built for anchovy from the trawl catches (Thalassa hauls) and samples from commercial vessels. We took the otoliths from a given number of fishes per length class (4 to 6 / half-cm), for a total amount of around 40 fishes per haul. As there was a lot of fishing operations where anchovy was present (as previous surveys), the number of otoliths taken during the survey was still important (1908 otoliths of anchovy taken and read on board), The population length distributions were estimated by a weighted use of length distributions in the hauls, weighted as described in section 3.2.

**Table 3.3.1.** PELGAS2018 anchovy Age/Length key.

| Nombre de age | age | | | | |
|---|---|---|---|---|---|
| length | 1 | 2 | 3 | 4 | Total |
| 8 | 100.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 8.5 | 100.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 9 | 100.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 9.5 | 100.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 10 | 100.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 10.5 | 100.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 11 | 98.77% | 1.23% | 0.00% | 0.00% | 100.00% |
| 11.5 | 93.64% | 6.36% | 0.00% | 0.00% | 100.00% |
| 12 | 92.80% | 7.20% | 0.00% | 0.00% | 100.00% |
| 12.5 | 88.55% | 11.45% | 0.00% | 0.00% | 100.00% |
| 13 | 84.83% | 13.10% | 2.07% | 0.00% | 100.00% |
| 13.5 | 71.32% | 27.94% | 0.74% | 0.00% | 100.00% |
| 14 | 39.16% | 57.34% | 3.50% | 0.00% | 100.00% |
| 14.5 | 36.24% | 62.42% | 0.67% | 0.67% | 100.00% |
| 15 | 17.68% | 81.10% | 1.22% | 0.00% | 100.00% |
| 15.5 | 8.05% | 87.92% | 3.36% | 0.67% | 100.00% |
| 16 | 4.55% | 88.64% | 6.06% | 0.76% | 100.00% |
| 16.5 | 3.09% | 86.60% | 9.28% | 1.03% | 100.00% |
| 17 | 0.00% | 86.49% | 9.46% | 4.05% | 100.00% |
| 17.5 | 0.00% | 72.34% | 27.66% | 0.00% | 100.00% |
| 18 | 0.00% | 84.62% | 7.69% | 7.69% | 100.00% |
| Total | 52.78% | 43.92% | 2.88% | 0.42% | 100.00% |

Applying the age distribution to the abundance in biomass and numbers, the distribution in age of the biomass has been calculated. The total biomass used here has been updated with the value obtained from the previous method based on strata.

Age distribution is shown in figures 3.3.2. The age distributions compared from 2000 to 2018 are shown in figure 3.3.3.

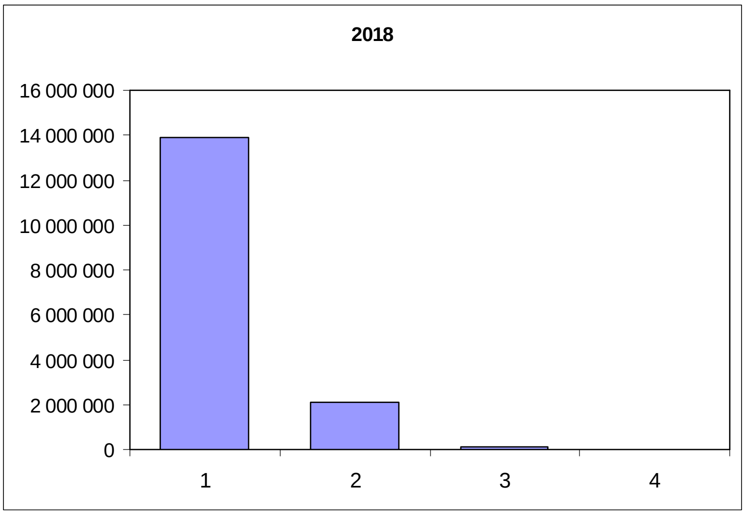



**Figure 3.3.2ï** global age composition (numbers) of anchovy as observed during PELGAS18.

Looking at the numbers at age since 2000 (fig 3.3.3.), the number of 1 year old anchovies this year seems to be equivalent to 2011, 2012 or 2017, far away from the very best recruitment observed in 2015.

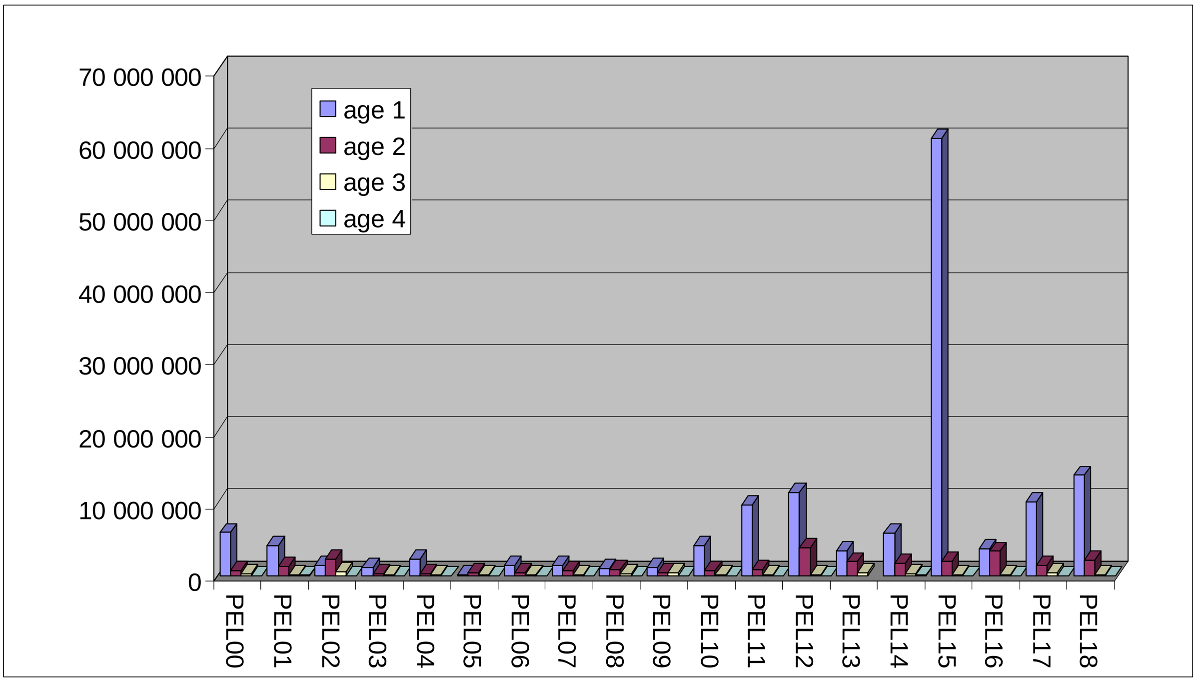



**Figure 3.3.3** Anchovy numbers at age as observed during PELGAS surveys since 2000

The huge 2015 age class is not followed in 2016 and in 2017 as well. Once again, it could indicate that an overestimation occurred on the recruitment in 2015. Several investigation have been done to explain, without results for the time being.

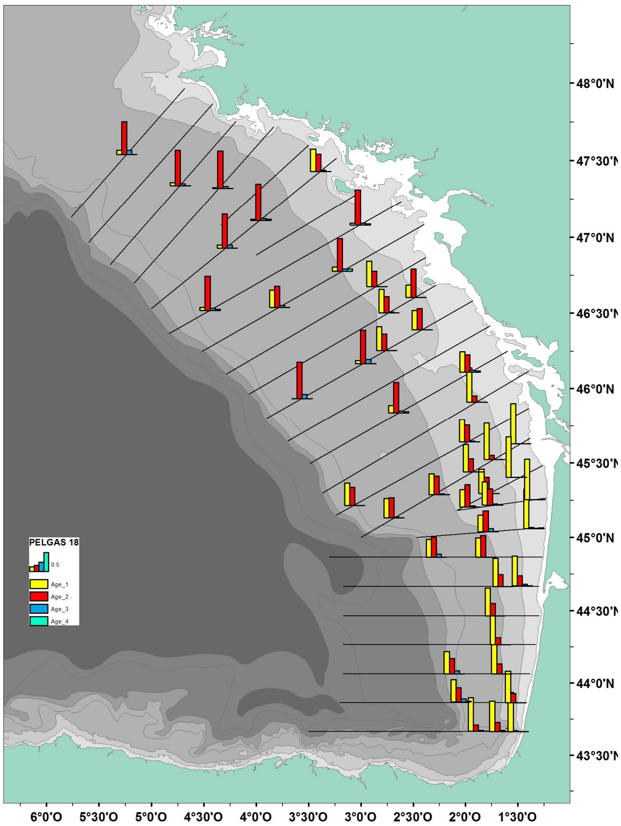


**Figure 3.3.4** Anchovy proportion at age in each haul as observed during PELGAS18 survey (yellow = age 1, red = age 2).

During previous surveys, anchovy was well geographically stratified depending on the age (*see WD 2010, Direct assessment of small pelagic fish by the PELGAS10 acoustic survey, Masse J and Duhamel E.*). It is less true this year, as in recent years, as age 1 were present all over the area where anchovy was present. This one year old anchovy is almost pure front of the Gironde, and mixed with older individuals elsewhere except on the great mud bank (North-West of the bay of Biscay) where almost pure anchovy of age 2 appeared close to the surface.

| | PEL18 - N - % |
|---|---|
| 1 | 86.3% |
| 2 | 13.1% |
| 3 | 0.6% |
| 4 | 0.05% |

| age | PEL18 - W - % |
|---|---|
| 1 | 73.52% |
| 2 | 25.10% |
| 3 | 1.24% |
| 4 | 0.14% |

**Figure 3.3.5** percentage by age of the Anchovy population observed during PELGAS18 in numbers (left) and biomass (right).

## 3.4. Weight/Length key

Based on 1921 weights of individual fishes, the following weight/length key was established (figure 4.5.):

$W= 0.003363L^{3.267418}$ with R2 = 0.9682 *(with W in grams and L in cm)*

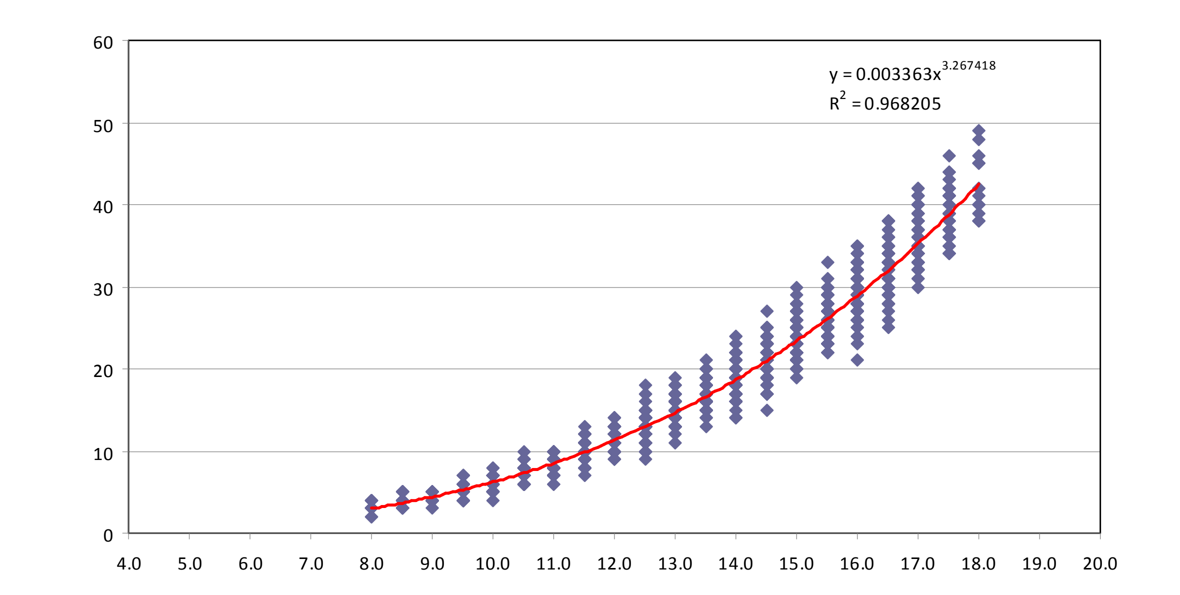



**Fig. 3.4** ï Weight/length key of anchovy established during PELGAS18

## 3.5. Mean Weight at age

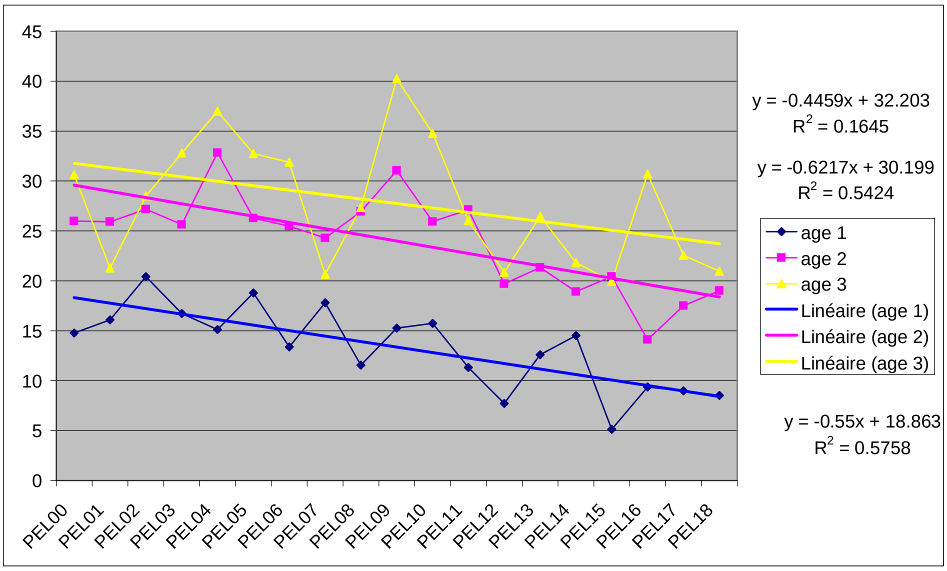



**Fig. 3.5.** ï evolution of mean weight at age (g) of anchovy along PELGAS series

As previous years, we observe that globally the trend of the mean weight at age is a decrease. This trend is almost the same for sardine in the bay of Biscay. Further investigates should be done and, if we have some hypothesis (maybe an effect of density-dependance), we do not have real explanation for the time being.

## 3.6. Eggs

During this survey, in addition of acoustic transects and pelagic trawl hauls, 681 CUFES samples were collected and counted, 64 vertical plankton hauls and 97 vertical profiles with CTD were carried out. Eggs were sorted and counted automatically with the zoocam system, and staged during the survey.

2018, as from 2011, was marked by a large quantity of collected and counted anchovy eggs (Fig 3.6.2), with the same magnitude as previous values of the on-going decade. Their spatial pattern of distribution was quite usual, with major part of the abundance South of 46°N. However, eggs are also abundant on 3 more transects than usual North of the Gironde estuary, with a connection all over the shelf between the classical inshore and slope distributions. This may be related to the large extension of the Gironde plume to the North-West, as well as the large adult abundance spreading larger than usual. South of the Gironde eggs are almost everywhere. The weather and hydrology conditions were slightly delayed as compared to climatologies, which may explain the relatively lower spawning as compared to previous years. Spawning distribution was strongly dispersed, probably in relation to the large extension of the plumes over the shelf.

Spawning occured over the mid-shelf in the north, an area where no egg is observed usually.

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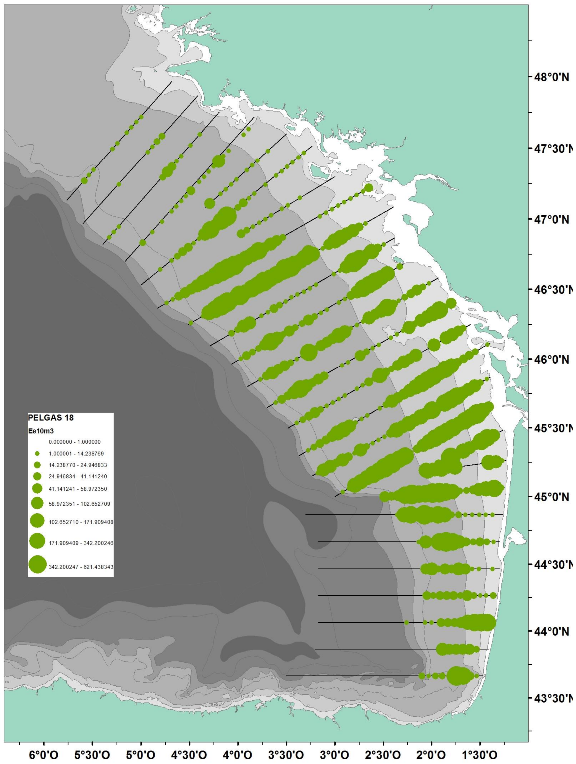


**Figure 3.6.1** ï Distribution of anchovy eggs observed with CUFES during PELGAS18.

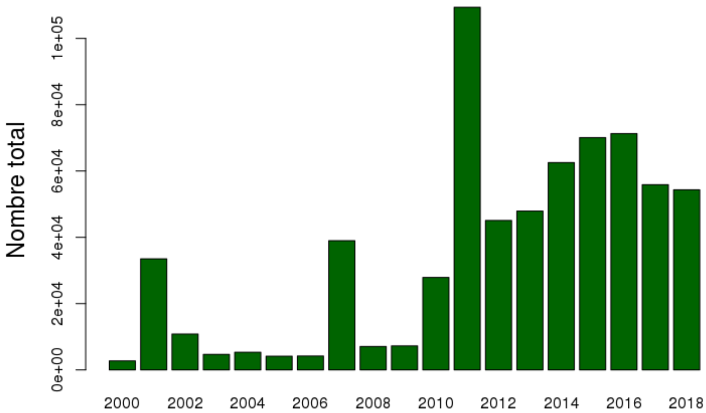


**Figure 3.6.2** ï Number of eggs observed during PELGAS surveys from 2000 to 2018

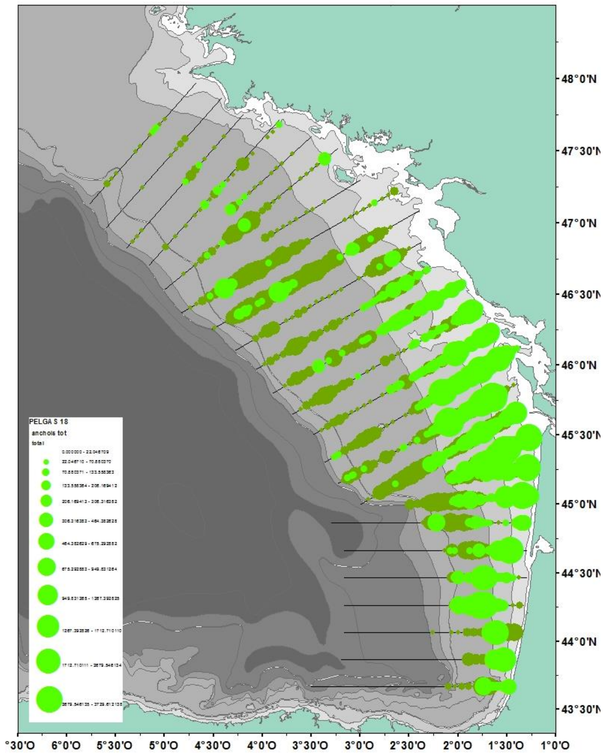


**Figure 3.6.3** ï Coherence between spatial distribution of adults and eggs. light green = biomass of adults per ESDU, dark green = eggs

We can see that globally the spatial distribution of eggs match with the adult's one along the coast. But more offshore between 45°N and 47°N, eggs were counted in important quantity with low echoes attributed to anchovy. It could be due to the presence of fish completely closed to the surface, in the blind layer of echosounders.

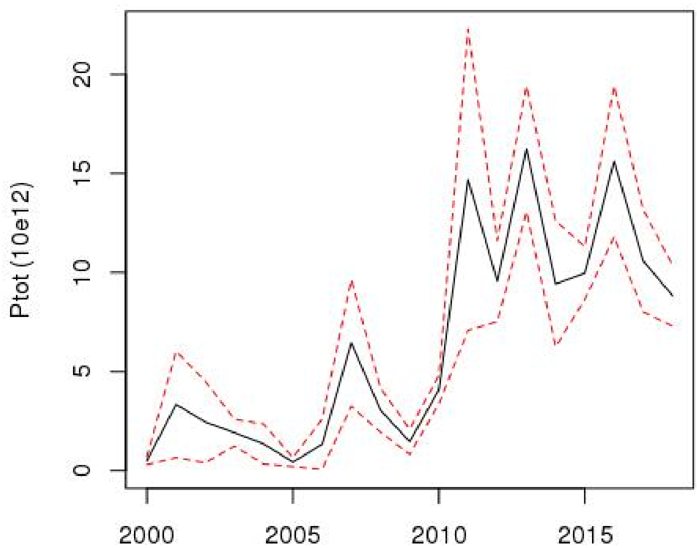


**Figure 3.6.4** ï total number of anchovy eggs corrected by the vertical model (Ptot)

# 4. Sardine data

## 4.1. Adults

The biomass estimate of sardine observed during PELGAS18 is **265 500** tons (table 2.3.), which constitutes an decrease from last year, the biomass reaching a medium level of the PELGAS series. It must be noticed that the sardine abundance index is very variable, and it could be explained that this survey doesn't cover the total area of potential presence of sardine, and it is possible that some years, this specie could be present up to the North, in the Celtic sea, SW of Cornouailles or Western Channel where some fishery occurs. It is also possible that sometimes, a small fraction of the population could be present in very coastal waters, when the R/V Thalassa is unable to operate in those waters. The estimate is representative of the sardine present in the survey area at the time of the survey and can be therefore considered as an estimate of the Bay of Biscay (VIIIab) sardine population.

Sardine was distributed all along the French coast of the bay of Biscay, from the South to the North. The small sardine was present this year, pure along the Lande's coast where an upwelling occurred, rarely mixed with other species along the coast. Sardine appeared also present close to the surface in the middle of the platform in the Northern part of the Bay of Biscay (on the great mud bank) which is not his regular habitat. Offshore, close to the surface, along the shelfbreak, sardine was totally absent this year.

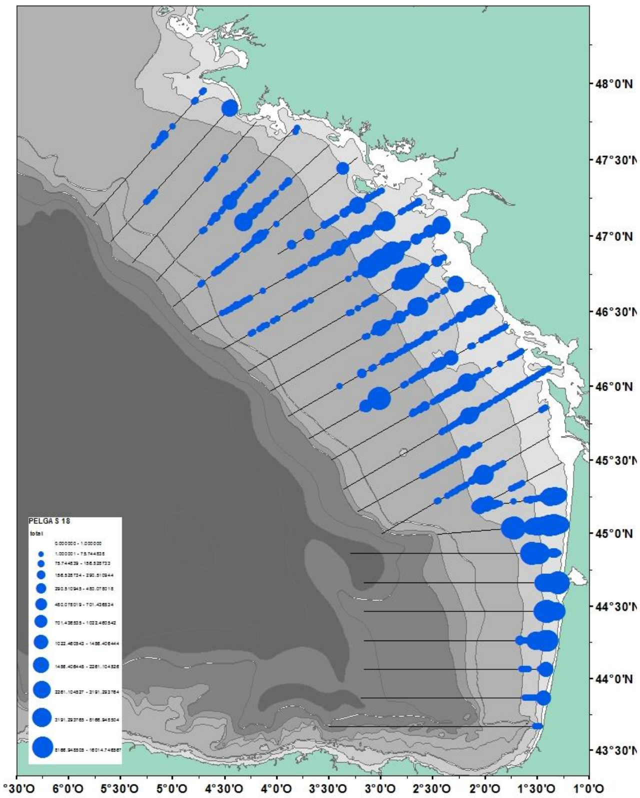


**Figure 4.1.1** ï distribution of sardine observed by acoustics during PELGAS18

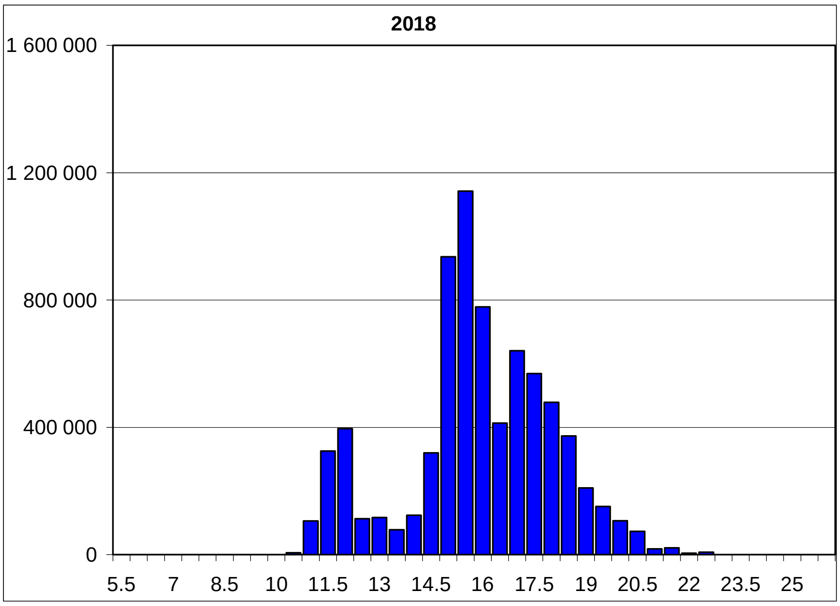


**Figure 4.1.2.** ï length distribution of sardine as observed during PELGAS18

Length distributions in the trawl hauls were estimated from random samples. The population length distributions have been estimated by a weighted average of the length distribution in the hauls. Weights used are the acoustic biomass estimated in the post-stratification regions comprising each trawl haul. The global length distribution of sardine is shown on figure 4.1.2.

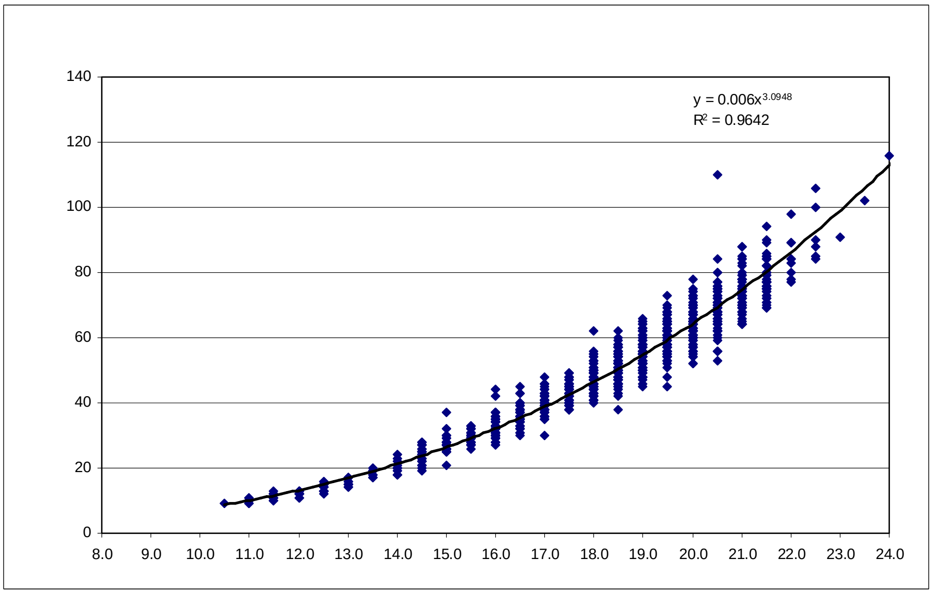


**Figure 4.1.3** ï Weight/length key of sardine established during PELGAS18

| Nombre de age | age | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| length | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | (vide) | Total |
| 10.5 | 100.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 11 | 100.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 11.5 | 100.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 12 | 100.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 12.5 | 100.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 13 | 100.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 13.5 | 100.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 14 | 90.00% | 10.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 14.5 | 100.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 15 | 100.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 15.5 | 98.72% | 1.28% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 16 | 96.63% | 3.37% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 16.5 | 58.43% | 41.57% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 17 | 23.48% | 75.65% | 0.87% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 17.5 | 3.73% | 94.03% | 0.75% | 1.49% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 18 | 0.00% | 84.51% | 10.56% | 4.23% | 0.00% | 0.70% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 18.5 | 0.00% | 64.86% | 17.57% | 14.86% | 2.70% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 19 | 0.00% | 53.33% | 16.67% | 23.33% | 5.83% | 0.83% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 19.5 | 0.00% | 22.32% | 20.54% | 43.75% | 11.61% | 1.79% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 20 | 0.00% | 9.65% | 14.91% | 50.88% | 20.18% | 3.51% | 0.88% | 0.00% | 0.00% | 0.00% | 100.00% |
| 20.5 | 0.00% | 3.30% | 3.30% | 58.24% | 26.37% | 5.49% | 1.10% | 2.20% | 0.00% | 0.00% | 100.00% |
| 21 | 0.00% | 0.00% | 1.61% | 40.32% | 48.39% | 9.68% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 21.5 | 0.00% | 0.00% | 2.13% | 31.91% | 46.81% | 17.02% | 2.13% | 0.00% | 0.00% | 0.00% | 100.00% |
| 22 | 0.00% | 0.00% | 0.00% | 33.33% | 44.44% | 11.11% | 11.11% | 0.00% | 0.00% | 0.00% | 100.00% |
| 22.5 | 0.00% | 0.00% | 0.00% | 0.00% | 66.67% | 33.33% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 23 | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 23.5 | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 24 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 24.5 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% | 0.00% | 100.00% |
| (vide) | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! |
| Total | 26.61% | 37.81% | 7.11% | 17.19% | 8.76% | 2.04% | 0.26% | 0.13% | 0.07% | 0.00% | 100.00% |

**Table 4.1.4 :** sardine age/length key from PELGAS18 samples (based on 1518 otoliths from Thalassa and commercial vessels)

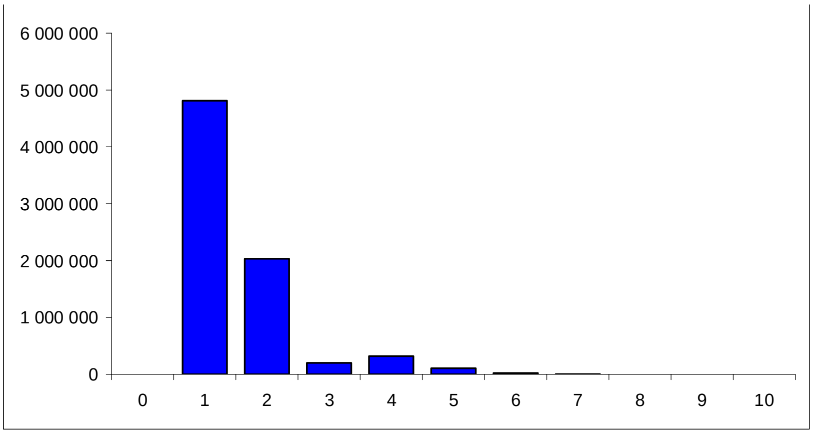


**Figure 4.1.5.-** Global age composition (nb) of sardine as observed during PELGAS 18

| | PEL18 - N - % |
|---|---|
| 1 | 64.14% |
| 2 | 27.10% |
| 3 | 2.68% |
| 4 | 4.25% |
| 5 | 1.44% |
| 6 | 0.32% |
| 7 | 0.04% |
| 8 | 0.02% |
| 10 | 0.00% |

| age | PEL18 - W- % |
|---|---|
| 1 | 48.20% |
| 2 | 36.20% |
| 3 | 4.50% |
| 4 | 7.46% |
| 5 | 2.86% |
| 6 | 0.66% |
| 7 | 0.08% |
| 8 | 0.05% |
| 9 | 0.00% |
| 10 | 0.00% |

**Figure 4.1.6** percentage by age of the sardine population observed during PELGAS18 in numbers (left) and biomass (right).

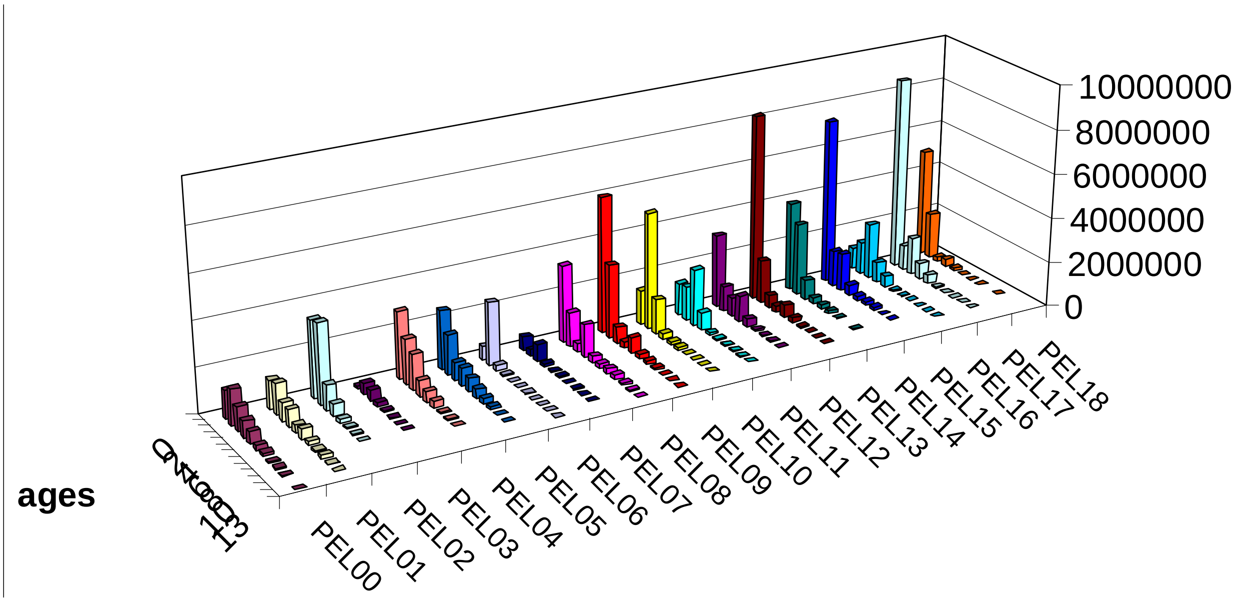


**Figure 4.1.7-** Age composition of sardine as estimated by acoustics since 2000

PELGAS serie of sardine abundances at age (2000-2018) is shown in Figure 4.1.7. Cohorts can be visually tracked on the graph particularly in the past : the respectively very low and very high 2005 and 2008 cohorts denote atypical years in terms of environmental conditions, and therefore fish (and particularly sardine) distributions. This is less true in recent years, with the good recruitment in 2013 which doesn't profit to incoming years, or the 2017 year class which seems to be the best recruitment ever and who seems to contribute not that much to the total abundance of sardine in 2018 in the bay of Biscay.

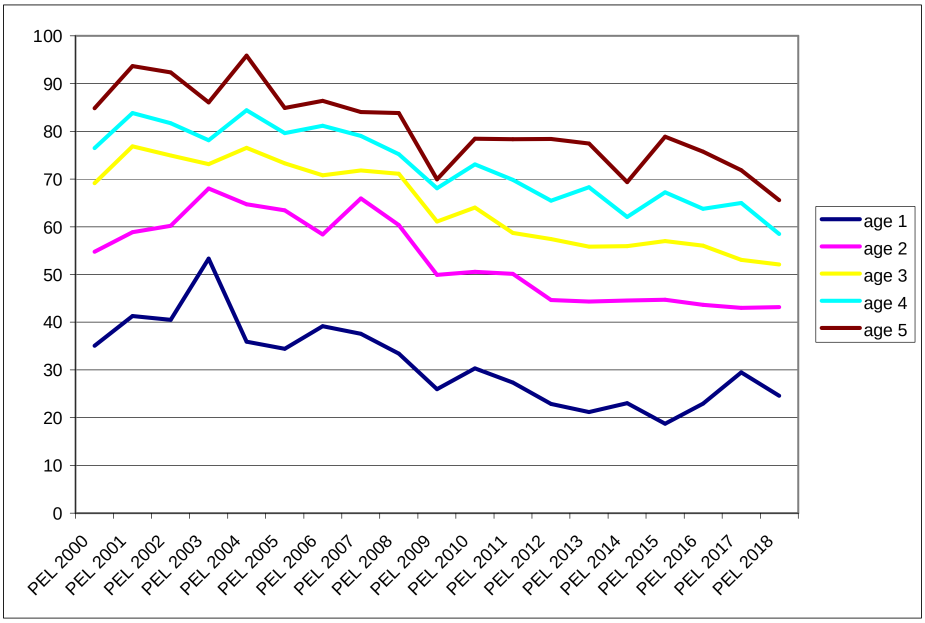


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**Figure 4.1.8-** evolution of mean weight at age (g) of sardine along pelgas series

The PELGAS sardine mean weights at age series (Figure 4.1.8) shows a clear decreasing trend, whose biological determinant is still poorly understood. It must be noticed that after two years when the mean weight at age 1 seems increasing, 2018 shows a decrease again. For older ages, (particularly age 2), there is no real evolution since 2011.

Further work must be conducted to explore the causes of the fluctuation of mean weights at ages.

## 4.2. Eggs

The spatial pattern of sardine eggs overlaps with the one of anchovy, without any distribution along the shelf break this year.

Sardine egg production was quite low (third lowest of the series), despite the delayed warming and stratification more favorable to sardine. Sardine eggs were indeed really low in the south of the Bay, and did not extend much in the north excepts along the coast until the latitude of the Loire.

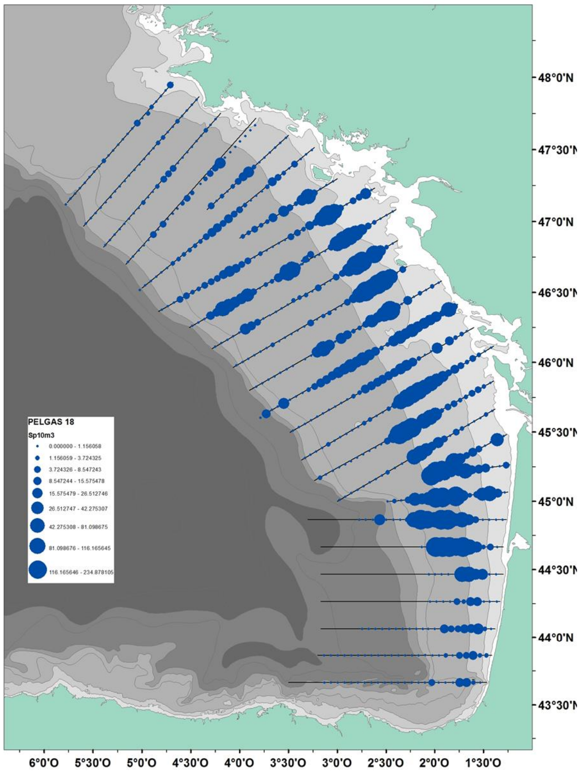


**Figure 4.2.1.** Distribution of sardine eggs observed with CUFES during PELGAS18.

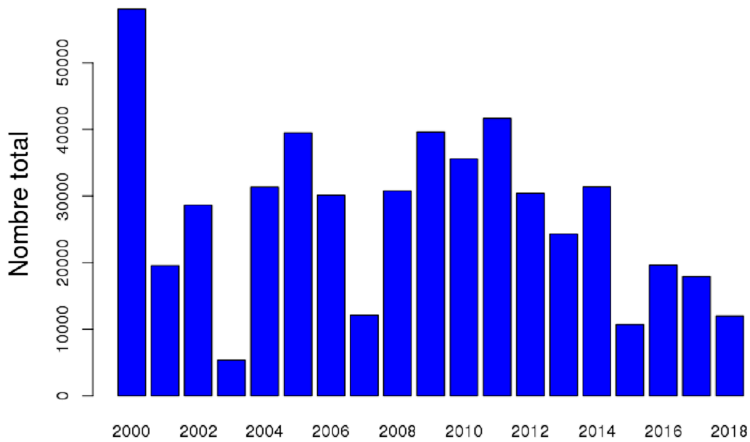


**Figure 4.2.2.** Number of eggs observed during PELGAS surveys from 2000 to 2018

2018 was marked by a low abundance of sardine eggs as compared to the PELGAS time-series. It must be noticed that this year almost all sardines were mature and in spawning period, except very few fishing hauls in the South along the coast where 1 year old sardine was present in a zone where an upwelling occured. This fish was just starting his maturation.

# 5. Top predators

For the sixteenth consecutive year, monitoring program to record marine top predator sightings (marine birds and cetaceans) has been carried out, during the whole coverage of the transects network.

A total of 270 hours of sighting effort were performed for 31 days (Figure 5.1.), with an average of 8 hours and 4à minutes of sighting effort per day. Weather conditions were globally very good with 86% of the time with good conditions (wind speed equal or less than 3 on the Beaufort scale).

During the survey, 4362 sightings of animals or objects were recorded. Seabirds constitute the majority of sightings (69%). Second most important sightings in numbers are litters drifting at sea (16%), then human activities (10 %). Cetaceans represents 5% of sightings (2% last year) and large fishes (sunfishes, sharks).

## 5.1 ï Sighting effort and conditions

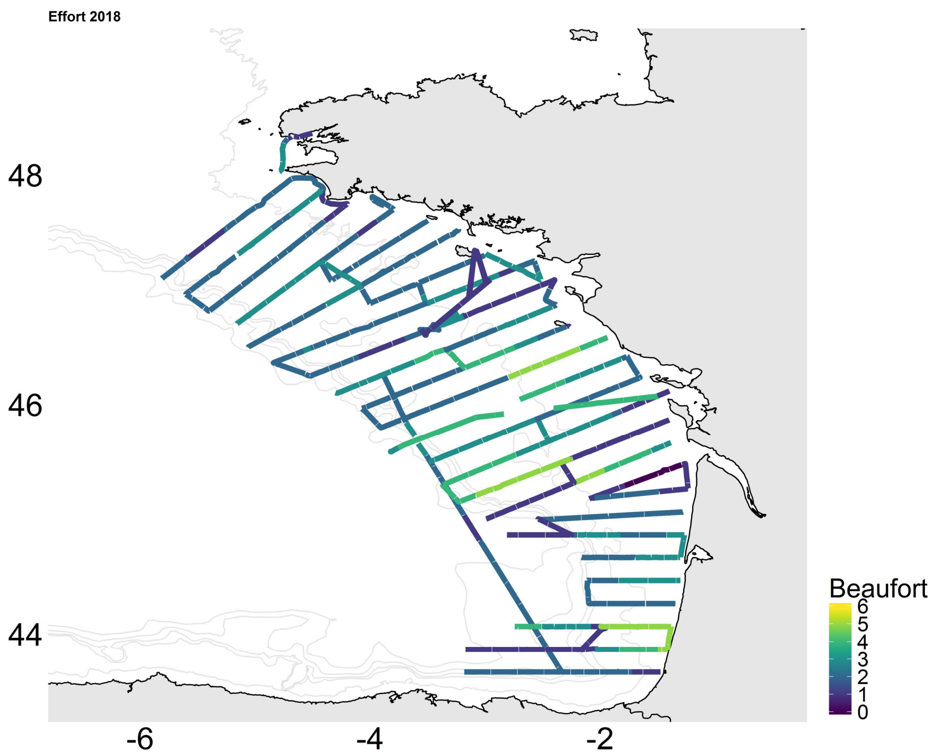


**Figure 5.1.** Sighting effort and conditions

The worst conditions were met in the central part of the bay of Biscay, and are mainly due to rain and fog. Globally, conditions of sightings during PELGAS2018 (including rain, fog and wind) were considered as very good.

## 5.2 ï Birds

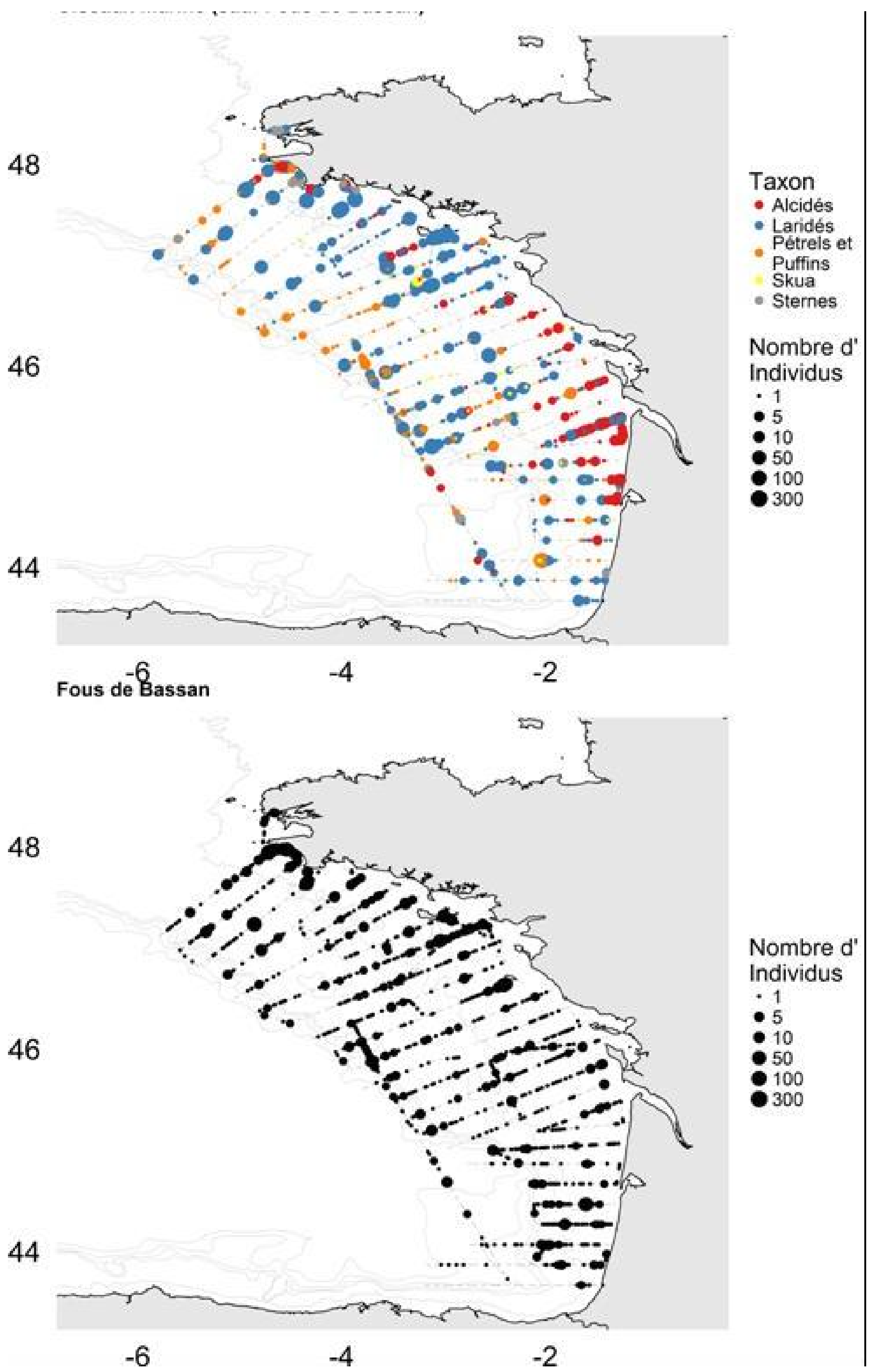


**Figure 5.2.** Distribution of birds observed during the PELGAS18 survey. On top : all marine birds without gannets. Bottom : gannets

Birds constitute the vast majority of sightings. Shorebirds and passerines accounted for less than 4% of bird sightings. 3009 sightings of seabirds were found all over the Bay of Biscay (Figure 5.2), divided into 26 identified species and a raw estimate of 7716 individuals (against 14 697 individuals in 2017), and constitutes a come back to the numbers observed until 2016.

Northern gannets accounted for 36% of all seabird sightings: its distribution is homogeneous across the Bay of Biscay.

The larids, principally including the sea gulls are mainly located (sometimes in very numerous groups) from the coast to the middle of the platform.

## 5.2 ï Mammals

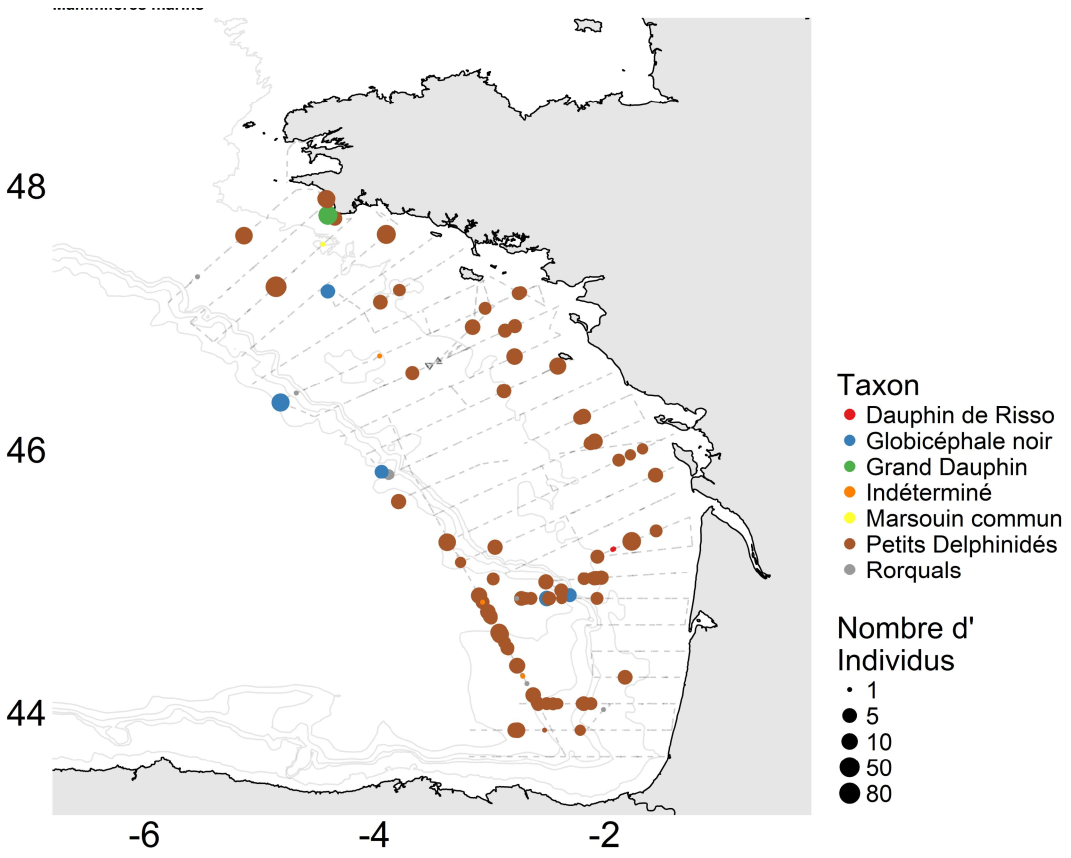


**Figure 5.2.** Distribution of mammals during the PELGAS18 survey.

A total of 188 sightings (against 88 last year) were recorded corresponding to a raw estimate of 794 individuals and 7 species of cetaceans clearly identified (Figure 5.2). The greatest diversity of marine mammals was observed in the central part of the Bay of Biscay. The overall distribution pattern is similar to that of previous PELGAS spring surveys.

The raw number of cetacean observed this years is similar as last year's number while the number of sightings strongly increased, because the most part of delphinids groups were constituted of 5 individuals or less.

Common dolphin is the most recorded species (74% of total observations, 629 individuals). Common dolphins were present on the continental shelf, particularly in the northern part of the Bay of Biscay. Offshore, there were located around the "fer à cheval" area.

No Striped dolphins were sighted this year again. However, few long-finned pilot whales were sighted on the continental slope in the central part of the Bay of Biscay and at the shelfbreak.

Very few bottlenose dolphins were detected this year (2 sightings), located close to the coast in the North of the bay of Biscay.

# 6. Hydrological conditions

Winter 2017-2018 has been really humid with a lot of rainfall. Cumulated river discharges (fig 6.1) to the Bay of Biscay have been really large, in second place after 2001 when considering the time-period 2000-2018, and first for the Gironde only.

Winter was also quite windy like early spring, which did not allow real stratification setup before the survey despite some nice days in April. .

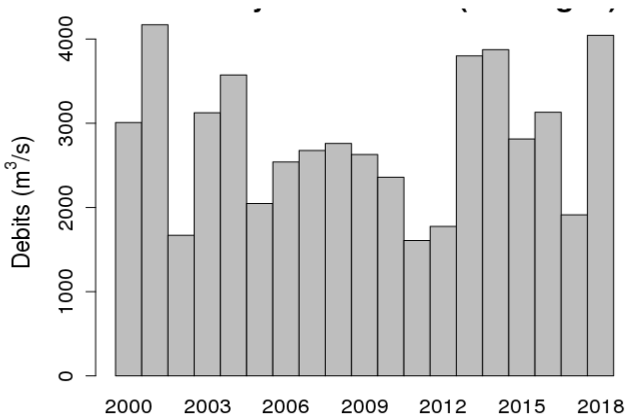


**figure 6.1** cumulated river discharges from January to April

Strong river discharges contributed to the haline stratification and shelf enrichment though, which together permitted winter blooms during calm periods as early as February.

During the survey, weather was calm but fresh under a northern flux, before becoming really anticyclonic and warmer during the second leg. Warming and thermal stratification were slow in the beginning but then accelerated in the second fortnight of May.

Salinity was low over the whole shelf especially within the 100m isobath, with values often below 33psu. An upwelling is visible along the Landes coast under the influence of the wind from the north, with a signature of low temperature and higher salinity.

Phytoplanktonic production was continuously high during a large part of the survey, again under the influence of the large river discharges.

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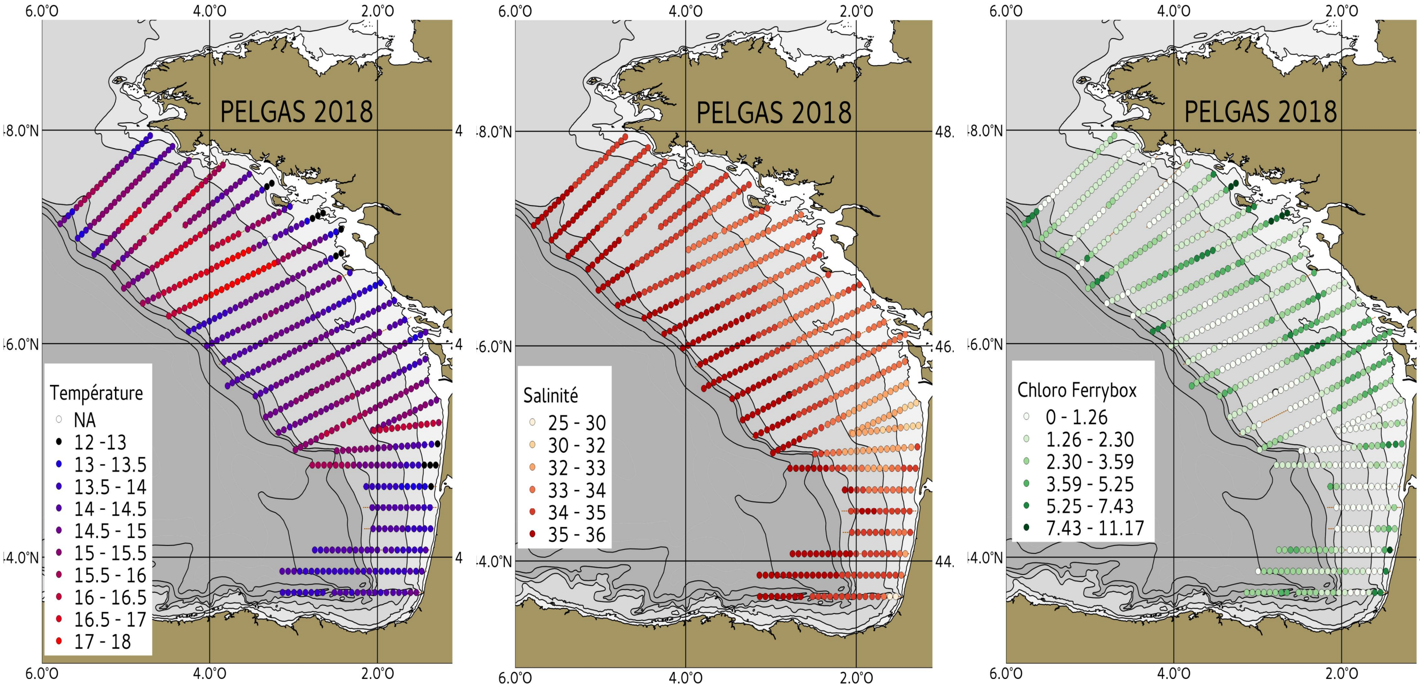


**Figure 6.2.** ï Surface temperature, salinity and fluorescence observed during PELGAS18.

# 7. CONCLUSION

The Pelgas18 acoustic survey has been carried out with good weather conditions (low wind) for the whole area, from the South of the bay of Biscay to the west of Brittany. The help of commercial vessels (two pairs of pelagic trawlers and a single one) during 17 days provided about 120 identification hauls instead of about 60 before 2007 when Thalassa was alone to identify echotraces. Their participation increased the precision of identification of echoes and some double hauls permitted to confirm that results provided by the two types of vessels (R/V and fishing boats) were comparable and usable for biomass estimate purposes. These commercial vessels participated to the PELGAS survey in a very good spirit of collaboration. Vessels (and the scientific observer onboard) are founded by EMFF (European Maritime and Ficheries Found) for the period 2017- 2019, with the financial help of "France Filière Pêche" which is a groupment of French fishing organisations.

Warming and thermal stratification were slow in the beginning but then accelerated in the second fortnight of May. Salinity was low over the whole shelf especially within the 100m isobath, with values often below 33psu. This low salinity is due to a very rainy winter before the survey. Cumulated river discharges to the Bay of Biscay have been really large, in second place after 2001 when considering the time-period 2000-2018

The PELGAS18 survey observed a relatively high level of anchovy biomass (**185 500 tons**), which seems to be higher to previous year, comparable to 2012 and far away from the 2015 biomass (which was probably overestimated but it is not explained for the time being). Offshore, anchovies were present closed to the surface in the South. As previous years, we observe that globally the trend of the mean weight at age is a decrease. This trend is globally the same for sardine in the bay of Biscay. Further investigates should be done and, if we have some hypothesis (maybe an effect of density-dependance), we do not have real explanation for the time being.

The biomass estimate of sardine observed during PELGAS17 is **265 500** tons, which constitutes an decrease from last year, the biomass reaching a medium level of the PELGAS series.. It confirms that this specie shows a variable abundance in the bay of Biscay at this period.

The population of sardine is still very young, with an age distribution largely dominated by age 1 and 2 groups (sum about 91% in numbers). The global age structure of the population and his evolution trough years confirms the validity of age readings and the fact that we can follow sardine cohorts in the sardine population of the bay of Biscay. But it must be noticed that global weights and lengths at age are regularly decreasing in the bay of Biscay, maybe due to an effect of density-dependence or other reasons not well known at this time. Old individuals (>5 years old) seems to be less an less present in the bay of Biscay, year after year.

Concerning the other species, mackerel was relatively well present this year compared to recent surveys, while sprat and blue whiting were rather absent in the surveyed area.

# Annex 3.5: Acoustic assessment and distribution of anchovy and sardine in ICES Subdivision 9a South during the ECOCADIZ 2018-07 Spanish survey (July-August 2018) with notes on the distribution of other pelagic species

*Please see report on next page.*

Working document presented in the ICES Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas 7, 8 and 9 (WGACEGG). Nantes, France, 19-23 November 2018.

# Acoustic assessment and distribution of anchovy and sardine in ICES Subdivision 9a South during the *ECOCADIZ 2018-07* Spanish survey (July-August 2018) with notes on the distribution of other pelagic species.

By

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## ABSTRACT

The present working document summarises a part of the main results obtained from the Spanish (pelagic ecosystem-) acoustic survey conducted by IEO between 31st July and 13rd August 2018 in the Portuguese and Spanish shelf waters (20-200 m isobaths) off the Gulf of Cadiz onboard the R/V *Miguel Oliver*. The 21 foreseen acoustic transects were sampled. A total of 25 valid fishing hauls were carried out for echo-trace ground-truthing purposes. This working document only provides abundance and biomass estimates for anchovy and sardine, which are presented with age structure only for anchovy. The distribution of all the mid-sized and small pelagic fish species susceptible of being acoustically assessed is also shown from the mapping of their back-scattering energies. Chub mackerel was the most frequent species in the fishing hauls, followed by sardine, anchovy, mackerel and bogue. *Trachurus* spp. showed a medium relative frequency of occurrence. Pearlside, snipefish and boarfish only occurred in hauls conducted in the deepest limit of the surveyed area. Anchovy was the most abundant species in these hauls, followed by silvery lightfish, sardine and chub mackerel, with the remaining species showing negligible relative contributions. The estimate of total NASC allocated to the "pelagic fish species assemblage" has been the highest one ever recorded within the time series, denoting a high fish density during the survey. Anchovy was widely distributed over the surveyed area, although showing the highest densities in the Spanish shelf waters and in a secondary nucleus located over the western Portuguese shelf. Largest (and oldest) anchovies were distributed both in the westernmost and easternmost waters and the smallest (and youngest) ones were concentrated in the surroundings of the Guadalquivir river mouth and adjacent shallow waters, including those ones in front of the Bay of Cadiz. Anchovy acoustic estimates in summer 2018 were of 3 063 million fish and 34 908 t (i.e. the second historical biomass maximum in the time-series), well above the historical average (ca. 22 kt), but without showing any clear recent trend. Sardine recorded a very high acoustic echo-integration in summer 2018 as a consequence of the occurrence of very dense mid-water schools in the coastal fringe (20-50 m depth) comprised between Tavira and the surroundings of the Guadalquivir river mouth. The distribution pattern of acoustic densities is quite similar to the one provided by the *PELAGO 18* survey in spring although the occurrence of sardine in the surveyed area was more continuous in summer. These facts resulted in summer estimates of 7 955 million fish and 114 631 t, the historical maximum record in terms of abundance and the second maximum in biomass. Spanish waters concentrated the bulk of the population. Such an increasing trend seems to be the result of a greater accessibility of the species to the survey, with the occurrence of many dense schools in the shallowest limits of the surveyed area not usually recorded in the most recent years. In any case, this behaviour should be analysed in more detail between WGACEGG experts.

## INTRODUCTION

The *ECOCADIZ* surveys constitute a series of yearly acoustic surveys conducted by IEO in the Subdivision 9a South (Algarve and Gulf of Cadiz, between 20 – 200 m depth) under the "pelagic ecosystem survey" approach onboard R/V *Cornide de Saavedra* (until 2013, since 2014 on onboard R/V *Miguel Oliver*). This series started in 2004 with the *BOCADEVA 0604* pilot acoustic - anchovy DEPM survey. The following surveys within this new series (named *ECOCADIZ* since 2006 onwards) are planned to be routinely performed on a yearly basis, although the series, because of the available ship time, has shown some gaps in those years coinciding with the conduction of the triennial anchovy DEPM survey (the true *BOCADEVA* series, which first survey started in 2005).

Results from the *ECOCADIZ* series are routinely reported to ICES Expert Groups on both stock assessment (formerly in WGMHSA, WGANC, WGANSA, at present in WGHANSA) and acoustic and egg surveys on anchovy and sardine (WGACEGG).

The present Working Document advances some results from the *ECOCADIZ 2018-07* survey. These results will only refer to the acoustic estimates (age-structured ones only for anchovy) and spatial distribution of anchovy and sardine and to inferences on the spatial distribution of other pelagic species from the distribution of the acoustic energy attributed to each of these species.

## MATERIAL AND METHODS

The *ECOCADIZ 2018-07* survey was carried out between 31st July and 13rd August 2018 onboard the Spanish R/V *Miguel Oliver* covering a survey area comprising the waters of the Gulf of Cadiz, both Spanish and Portuguese, between the 20 m and 200 m isobaths. The survey design consisted in a systematic parallel grid with tracks equally spaced by 8 nm, normal to the shoreline (**Figure 1**).

Echo-integration was carried out with a *Simrad™ EK60* echo sounder working in the multi-frequency fashion (18, 38, 70, 120, 200 kHz). Average survey speed was about 10 knots and the acoustic signals were integrated over 1-nm intervals (ESDU). Raw acoustic data were stored for further post-processing using *Echoview™* software package. Acoustic equipment was previously calibrated during the *MEDIAS 2018* acoustic survey, a survey conducted in the Spanish Mediterranean waters just before the *ECOCADIZ* one, following the standard procedures (Demer *et al*., 2015).

Survey execution and abundance estimation followed the methodologies firstly adopted by the ICES *Planning Group for Acoustic Surveys in ICES Sub-Areas VIII and IX* (ICES, 1998) and the recommendations given by the *Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES areas 7, 8 and 9* (WGACEGG; ICES, 2006a,b).

Fishing stations for echo-trace ground-truthing were opportunistic, according to the echogram information, and they were carried out using a ca. 15 m-mean vertical opening pelagic trawl (*Tuneado* gear) at an average speed of 4 knots. Gear performance and geometry during the effective fishing was monitored with *Simrad™ Mesotech FS20/25* trawl sonar and a *Marport™ combi TE/TS* (Trawl Eye/Trawl Speed) sensor. Trawl sonar and sensors data from each haul were recorded and stored for further analyses.

Ground-truthing haul samples provided biological data on species and they were also used to identify fish species and to allocate the back-scattering values into fish species according to the proportions found at the fishing stations (Nakken and Dommasnes, 1975).

Length frequency distributions (LFD) by 0.5-cm class were obtained for all the fish species in trawl samples (either from the total catch or from a representative random sample of 100-200 fish). Only those LFDs based on a minimum of 30 individuals and showing a normal distribution were considered for the purpose of the acoustic assessment.

Individual biological sampling (length, weight, sex, maturity stage, stomach fullness, and mesenteric fat content) was performed in each haul for anchovy, sardine (in both species with otolith extraction), mackerel and horse-mackerel species, and bogue.

The following TS/length relationship table was used for acoustic estimation of assessed species (recent IEO standards after ICES, 1998 and recommendations by ICES, 2006a,b):

| **Species** | $b_{20}$ |
|---|---|
| **Sardine (*Sardina pilchardus*)** | -72.6 |
| **Round sardinella (*Sardinella aurita*)** | -72.6 |
| **Anchovy (*Engraulis encrasicolus*)** | -72.6 |
| **Chub mackerel (*Scomber japonicus*)** | -68.7 |
| **Mackerel (*S. scombrus*)** | -84.9 |
| **Horse mackerel (*Trachurus trachurus*)** | -68.7 |
| **Mediterranean horse-mackerel (*T. mediterraneus*)** | -68.7 |
| **Blue jack mackerel (*T. picturatus*)** | -68.7 |
| **Bogue (*Boops boops*)** | -67.0 |
| **Blue whiting (*Micromesistius poutassou*)** | -67.5 |
| **Silvery lightfish (*Maurolicus muelleri*)** | -72.2 |
| **Boarfish (*Capros aper*)** | -66.2* (-72.6) |

*Boarfish $b_{20}$ estimate following to Fässler *et al*. (2013). Between parentheses the usual IEO value considered in previous surveys.

The *PESMA 2010* software (J. Miquel, unpublished) has got implemented the needed procedures and routines for the acoustic assessment following the above approach.

A *Continuous Underway Fish Egg Sampler* (CUFES, 151 stations), a *Sea-bird Electronics™ SBE 21 SEACAT* thermosalinograph and a *Turner™ 10 AU 005 CE Field* fluorometer were used during the acoustic tracking to continuously monitor some hydrographical variables (sub-surface sea temperature, salinity, and *in vivo* fluorescence). Vertical profiles of hydrographical variables were also recorded by night from 161 CTD casts by using *Sea-bird Electronics™ SBE 911+ SEACAT* (with coupled *Datasonics* altimeter, *SBE 43* oximeter, *WetLabs ECO-FL-NTU* fluorimeter and *WetLabs C-Star 25 cm* transmissometer sensors) and *LADCP T-RDI WHS* 300 kHz profilers (**Figure 2**). *VMADCP RDI 150 kHz* records were also continuously recorded by night between CTD stations.

Twenty two (22) *Manta trawl* hauls were also carried out to characterize the distribution pattern of micro-plastics over the shelf (**Figure 3**). These hauls did not follow a pre-established sampling scheme although the main goal was to have samples well distributed both in the coastal and oceanic areas of the shelf. Consequently, the hauls were opportunistically carried out taking the advantage of the conduction of fishing hauls, the start or end of an acoustic transect or whatever discrete station devoted to the sampling of either hydrographical or biological variables which were close to the preferred depths.

Information on presence and abundance of sea birds, turtles and mammals was also recorded during the acoustic sampling by one onboard observer.

**RESULTS**

**Acoustic sampling**

The acoustic sampling started on 01st August in the coastal end of the transect RA01 and finalized on 11th August in the oceanic end of the transect RA21 (**Table 1, Figure 1**). Transects were acoustically sampled in the E-W direction. The whole 21-transect sampling grid was sampled. The acoustic sampling usually started at 06:00 UTC although this time might vary depending on the duration of the works related with the hydrographic sampling. The foreseen start of transects RA14 and RA15 by the coastal end had to be displaced into deeper waters in order to avoid the occurrence of open-sea fish farming/fattening cages.

**Groundtruthing hauls**

Twenty five (25) fishing operations, all of them being considered as valid ones according to a correct gear performance and resulting catches, were carried out (**Table 2**, **Figure 4**).

As usual in previous surveys, some fishing hauls were attempted by fishing over an isobath crossing the acoustic transect as close as possible to the depths where the fishing situation of interest was detected over that transect. In this way the mixing of different size compositions (*i.e.*, bi-, multi-modality of length frequency distributions) was avoided as well as a direct interaction with fixed gears. The mixing of sizes is more probable close to nursery-recruitment areas and in regions with a very narrow continental shelf. This type of hauls is also conducted in depths showing hard and/or very irregular bottoms. Given that all of these situations were not very uncommon in the sampled area, 40% of valid hauls (10 hauls) were conducted over isobath.

Because of many echo-traces usually occurred close to the bottom, all the pelagic hauls were carried out like a bottom-trawl haul, with the ground rope working over or very close to the bottom. According to the above, the sampled depth range in the valid hauls oscillated between 41-185 m.

During the survey were captured 1 Chondrichthyan, 29 Osteichthyes, 5 Cephalopod and 3 Crustacean species. The percentage of occurrence of the more frequent species in the trawl hauls is shown in the enclosed **text table below** (see also **Figure 5**). The pelagic ichthyofauna was the most frequently captured species set and the one composing the bulk of the overall yields of the catches. Within this pelagic fish species set, chub mackerel was the most frequent captured species in the valid hauls (24 hauls, 96% presence index) followed by sardine, anchovy, mackerel and bogue (with relative occurrences between 60-92%). *Trachurus* spp. showed a medium relative frequency of occurrence (ca. 20-48%), whereas silver lightfish (*Maurolicus muelleri*, 16%), snipefish (*Macrorhamphosus scolopax*, 8%) and boarfish (*Capros aper*, 4%) showed either a low or very low occurrence in the whole surveyed area. Round sardinella and blue whiting were absent in the hauls of the present survey.

For the purposes of the acoustic assessment, anchovy, sardine, mackerel species, horse & jack mackerel species, bogue, silver lightfish and boarfish were initially considered as the survey target species. All of the invertebrates, and both bentho-pelagic (*e.g.*, manta rays) and benthic fish species (*e.g.*, flatfish, gurnards, etc.) were excluded from the computation of the total catches in weight and in number from those fishing stations where they occurred. Catches of the remaining non-target species were included in an operational category termed as "*Others*".

According to the above premises, during the survey were captured a total of 20.5 tonnes and 954 thousand fish (**Table 3**). 38% of this fished biomass corresponded to chub mackerel, 31% to sardine, 26% to anchovy, and contributions lower than 1% to the remaining species. The most abundant species in ground-truthing trawl hauls was anchovy (39%) followed by silver light fish (27%), sardine (19%) and chub mackerel (15%), with the remaining species showing lower contributions than 0.1%.

| Species | # of fishing stations | Occurrence (%) | Total weight (kg) | Total number |
|---|---|---|---|---|
| ***Scomber colias*** | 24 | 96 | 7878,981 | 142227 |
| ***Sardina pilchardus*** | 23 | 92 | 6425,485 | 183976 |
| ***Merluccius merluccius*** | 23 | 92 | 101,66 | 874 |
| ***Engraulis encrasicolus*** | 22 | 88 | 5323,439 | 369728 |
| ***Scomber scombrus*** | 20 | 80 | 84,958 | 452 |
| ***Boops boops*** | 15 | 60 | 82,441 | 654 |
| ***Loligo subulata*** | 15 | 60 | 1,606 | 532 |
| ***Spondyliosoma cantharus*** | 13 | 52 | 51,951 | 356 |
| ***Loligo media*** | 13 | 52 | 1,696 | 583 |
| ***Trachurus trachurus*** | 12 | 48 | 74,959 | 703 |
| ***Trachurus picturatus*** | 12 | 48 | 5,301 | 76 |
| ***Loligo vulgaris*** | 9 | 36 | 1,427 | 37 |
| ***Pagellus erythrinus*** | 8 | 32 | 87,247 | 530 |
| ***Diplodus bellottii*** | 6 | 24 | 9,114 | 149 |
| ***Diplodus vulgaris*** | 6 | 24 | 47,125 | 296 |
| ***Aphia minuta*** | 6 | 24 | 0,119 | 203 |
| ***Trachurus mediterraneus*** | 5 | 20 | 48,755 | 275 |
| ***Diplodus annularis*** | 5 | 20 | 3,374 | 55 |
| ***Spicara flexuosa*** | 5 | 20 | 2,381 | 33 |
| ***Alosa fallax*** | 4 | 16 | 1,583 | 6 |
| ***Pagellus acarne*** | 4 | 16 | 6,491 | 33 |
| ***Trachinus draco*** | 4 | 16 | 0,518 | 4 |
| ***Maurolicus muelleri*** | 4 | 16 | 148,71 | 253722 |
| ***Pagellus bellottii*** | 3 | 12 | 5,815 | 31 |
| ***Mola mola*** | 2 | 8 | 13,5 | 4 |
| ***Illex coindetii*** | 2 | 8 | 0,134 | 4 |
| ***Macroramphosus scolopax*** | 2 | 8 | 0,056 | 16 |
| ***Capros aper*** | 1 | 4 | 1,375 | 304 |

The species composition, in terms of percentages in number, in each valid fish station is shown in **Figure 5**. A first impression of the distribution pattern of the main species may be derived from the above figure. Thus, anchovy showed a relatively wide distribution over the surveyed area, although the highest yields were recorded in the Spanish waters. The size composition of anchovy catches confirms the usual pattern exhibited by the species in the area during the survey season, with the largest fish inhabiting the westernmost waters and the smallest ones concentrated in the surroundings of the Guadalquivir river mouth and adjacent shallow waters (**Figure 6**). Sardine was also widely distributed in the surveyed area. Juvenile sardines were mainly captured in the shallowest hauls conducted in the coastal fringe between Tinto-Odiel river mouth and the Bay of Cadiz, with a secondary nucleus of occurrence in the surroundings of Cape Santa Maria (**Figure 7**). Chub mackerel, horse mackerel, blue jack mackerel and bogue, although they occurred in a great part of the study area, only showed relatively high yields in the Portuguese waters. Mediterranean horse mackerel was restricted to the easternmost Spanish waters. The size composition of these last species in fishing hauls is shown in **Figures 8** to **15**.

## Back-scattering energy attributed to the "pelagic assemblage" and individual species

A total of 335 nmi (ESDU) from 21 transects has been acoustically sampled by echo-integration for assessment purposes. From this total, 218 nmi (11 transects) were sampled in Spanish waters, and 117 nmi

(10 transects) in the Portuguese waters. The enclosed text table below provides the nautical area-scattering coefficients attributed to each of the selected target species and for the whole "pelagic fish assemblage".

| $S_A$ ($m^2$ $nmi^{-2}$) | Total spp. | PIL | ANE | MAC | MAS | HOM | HMM | JAA | BOG | BOC | MAV |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total Area (%)** | 241648 (100,0) | 117882 (48,8) | 44153 (18,3) | 27 (0,01) | 51973 (21,5) | 472 (0,2) | 1585 (0,7) | 41 (0,02) | 3585 (1,5) | 9 (0,004) | 21920 (9,1) |
| **Portugal (%)** | 65910 (27,3) | 20194 (17,1) | 4336 (9,8) | 5 (19,1) | 36521 (70,3) | 436 (92,3) | 0 (0,0) | 34 (83,3) | 1276 (35,6) | 9 (100,0) | 3100 (14,1) |
| **Spain (%)** | 182864 (72,7) | 97688 (82,9) | 39817 (90,2) | 22 (80,9) | 15453 (29,7) | 36 (7,7) | 1585 (100,0) | 7 (16,7) | 2309 (64,4) | 0 (0,0) | 18819 (85,9) |

For this "pelagic fish assemblage" has been estimated a total of 241 648 $m^2$ $nmi^{-2}$, the highest estimate ever recorded within the time-series (**Figure 16**). Portuguese waters accounted for 27% of this total back-scattering energy and the Spanish waters the remaining 73%. However, given that the Portuguese sampled ESDUs were almost the half of the Spanish ones, the (weighted-) relative importance of the Portuguese area (*i.e.*, its density of "pelagic fish") is actually much higher. The mapping of the total back-scattering energy is shown in **Figure 16**. By species, sardine (49%), chub mackerel (22%) and anchovy (18%) were the most important species in terms of their contributions to the total back-scattering energy. Silvery lightfish (9%), bogue (1.5%) and Mediterranean horse mackerel (1%) were the following species in importance. The remaining species contributed with less than 0.2% only.

Some inferences on the species' distribution may be carried out from regional contributions to the total energy attributed to each species: Mediterranean horse mackerel, anchovy, silvery lightfish, sardine, mackerel and bogue seemed to show greater densities in the Spanish waters, whereas chub mackerel, blue jack mackerel, horse mackerel and boarfish could be considered as typically "Portuguese species" in this survey.

According to the resulting values of integrated acoustic energy, the species acoustically assessed in the present survey finally were anchovy, sardine, mackerel, chub mackerel, blue jack mackerel, horse mackerel, Mediterranean horse mackerel, bogue.

**Spatial distribution and abundance/biomass estimates**

**Anchovy**

Parameters of the survey's length-weight relationship for anchovy are given in **Table 4**. The back-scattering energy attributed to this species and the coherent strata considered for the acoustic estimation are shown in **Figure 17**. The estimated abundance and biomass by size and age class are given in **Tables 5** and **6**, and **Figures 18** and **19**.

Anchovy was widely distributed over the surveyed area, although showing the highest densities in the Spanish shelf waters between El Rompido (RA10) and Bay of Cadiz (RA03), and in a secondary nucleus located over the Portuguese shelf, between Alfanzina (RA18) and Cape of Santa Maria (RA15) (**Figure 17**). This distribution pattern differed from the exhibited one during the *PELAGO* spring survey, when anchovy was restricted to a zone comprised between Vila Real Sto. Antonio (easternmost Portuguese waters) and the Bay of Cadiz.

Twelve (12) coherent post-strata have been differentiated according to the $S_A$ value distribution and the size composition in the fishing stations (**Figure 17**). The acoustic estimates by homogeneous post-stratum and total area are shown in **Tables 5** and **6** and **Figures 18** and **19**. Overall acoustic estimates in summer 2018 were of 3 063 million fish and 34 908 tonnes. By geographical strata, the Spanish waters yielded 93%

(2 839 million) and 88% (30 683 t) of the total estimated abundance and biomass in the Gulf, confirming the importance of these waters in the species' distribution. The estimates for the Portuguese waters were 224 million and 4 225 t. The current biomass estimate (34 908 t) becomes in the second historical maximum within the time-series (2006: 35 539 t; 2016: 34 184 t; see **Figure 31**). The *PELAGO 18* spring Portuguese survey previously estimated for this same area 23 473 t (2 157 million): 4 328 t (300 million) in Portuguese waters and 19 145 t (1 857 million) in Spanish waters.

The size class range of the assessed population varied between the 9.0 and 17.0 cm size classes, with one main modal class at 12.0 cm. The size composition of anchovy by coherent post-strata confirms the usual pattern exhibited by the species in the area during the spawning season, with the largest (and oldest) fish being distributed both in the westernmost and easternmost waters and the smallest (and youngest) ones concentrated in the surroundings of the Guadalquivir river mouth and adjacent shallow waters, including those ones in front of the Bay of Cadiz (**Table 5; Figures 18** and **19;** see also **Figure 6**).

The population was composed by fishes not older than 2 years. As it has been happening in the last years, during the 2018 survey some recruitment (age 0 fish) has also been recorded, probably as a consequence of the delayed survey dates. In fact, age 0 fish accounted for 46 and 35% of the total estimated abundance and biomass, respectively. Age 1 fish represented 53% and 62% of the total abundance and biomass (**Table 6**; **Figure 19**).

The Gulf of Cadiz anchovy egg distribution from CUFES sampling is shown in **Figure 20**. Anchovy egg distribution and densities in summer 2018 are quite coincident with that of adults. The estimated total egg density is at the same magnitude than the observed in the most recent years but such estimates are lower than the historical average. Notwithstanding the above, the extension of the spawning area was among the highest one ever recorded (the second historical peak in the series).

**Sardine**

Parameters of the survey's size-weight relationship for sardine are shown in **Table 4**. The back-scattering energy attributed to this species and the coherent strata considered for the acoustic estimation are shown in **Figure 21**. Estimated abundance and biomass by size and age class are given in **Tables 7** and **8** and **Figures 22** and **23**.

Sardine recorded a very high acoustic echo-integration in summer 2018 as a consequence of the occurrence of very dense mid-water schools in the coastal fringe (20-50 m depth) comprised between Tavira (RA13) and the surroundings of the Guadalquivir river mouth (RA05; see **Annex** figures). The distribution pattern of acoustic densities is quite similar to the one provided by the *PELAGO* survey in spring although the occurrence of sardine in the surveyed area was more continuous in summer (**Figure 21**).

Fourteen (14) size-based homogeneous sectors were delimited for the acoustic assessment (**Figure 21**). The estimates of Gulf of Cadiz sardine abundance and biomass in summer 2018 were 7 955 million fish and 114 631 t, the historical maximum record in terms of abundance and the second maximum in biomass (the historical maximum was reached in 2006: 123 849 t; see **Figure 31**). Spanish waters concentrated the bulk of the population (7 239 million and 90 214 t). The estimates for the Portuguese waters were 716 million and 24 417 t. The *PELAGO 18* spring Portuguese survey previously estimated for this same area 58 561 t (6 680 million): 22 627 t (1 097 million) in Portuguese waters and 35 934 t (5 583 million) in Spanish waters.

Sizes of the assessed population ranged between 8.0 and 20.5 cm size classes. The length frequency distribution of the population was clearly bimodal, with one main mode at 11.5 cm size class and a secondary one at 17.0 cm (**Table 7**; **Figure 22**). The 2018 summer estimate of mean size (122 mm) is among the lowest estimates within the series. This fact might be explained by the relative importance of the juvenile fraction in the estimated population (≤11.5 cm), which was mainly located in relatively shallow waters in front of the Cape Santa Maria and along the coastal fringe comprised between the Guadiana and Guadalquivir river mouths and the Bay of Cadiz (**Table 7**; **Figure 22**; see also **Figure 7**). Such a decrease in mean size was coupled with a similar decreasing trend in the mean weight (14.4 g), which was well below the historical average. The contribution in biomass of the adult fraction in the assessed population (around at a main modal size class at 17.5 cm) may be not enough to compensate the greater relative contribution of juveniles.

**Mackerel**

Parameters of the survey's length-weight relationship are shown in **Table 4**. The distribution of the back-scattering energy attributed to this species is shown in **Figure 23**.

Atlantic mackerel showed very low acoustic records during the 2018 survey, which were mainly observed all over the shelf located in the central part of the Gulf of Cadiz (**Figure 23**).

**Chub mackerel**

Parameters of the survey's length-weight relationship are shown in **Table 4**. The distribution of the back-scattering energy attributed to this species is shown in **Figure 24**.

Contrarily to the pattern described for the Atlantic mackerel, the acoustic energy allocated to its close relative, Chub mackerel, accounted for 21.5% of the total acoustic energy attributed to fish in the survey. The population was mainly concentrated in the westernmost waters of the Gulf, between Cape San Vicente and Cape Santa Maria, with a secondary nucleus of fish density in the easternmost waters, from the Bay of Cadiz to the Strait of Gibraltar (**Figure 24**).

**Blue jack-mackerel**

The survey's length-weight relationship for this species is given in **Table 4**. The distribution of the back-scattering energy attributed to this species is illustrated in **Figure 25**.

The distribution pattern of the very low acoustic densities attributed to Blue jack mackerel closely resembled to the described one for horse mackerel (**Figure 25**).

**Horse mackerel**

The survey's length-weight relationship for horse mackerel is shown in **Table 4**. The back-scattering energy attributed to this species is shown in **Figure 26**

Horse mackerel showed very low acoustic densities in the surveyed area, with the species being almost absent in the easternmost shelf and showing relatively higher densities in the shelf area comprised between Cape San Vicente and Cape Santa Maria (**Figure 26**).

**Mediterranean horse-mackerel**

The survey's length-weight relationship for this species is shown in **Table 4**. Back-scattering energy attributed to the species is represented in **Figure 27**.

Mediterranean horse mackerel was restricted, as usual, to the Spanish waters, with the highest densities being recorded in the inner shelf waters of the central part of the Gulf (**Figure 27**).

**Bogue**

Parameters of the survey's length-weight relationship for bogue are shown in **Table 4**. Back-scattering energy attributed to bogue is shown in **Figure 28**.

Bogue was distributed practically all over the shelf of the surveyed area, although showed its highest densities over the inner shelf of both the central and westernmost waters of the Gulf (**Figure 28**).

**Boarfish**

The survey's length-weight relationship for this species is shown in **Table 4**. Back-scattering energy attributed to the species is represented in **Figure 29**.

Boarfish showed an incidental occurrence restricted to the outer shelf waters jus to the west of Cape of Santa Maria (**Figure 29**).

**Pearlside**

The survey's length-weight relationship for this species is shown in **Table 4**. Back-scattering energy attributed to the species is represented in **Figure 30**.

The constant occurrence of pearlside in somewhat shallower waters than usual in the 2018 survey has resulted in its acoustic detection in the surveyed area (9% of the total acoustic energy), just in the transition between outer shelf and upper slope waters. Higher densities were recorded in the Spanish outer shelf (**Figure 30**).

## (SHORT) DISCUSSION

The total NASC estimated in this survey for "pelagic fish assemblage", 241 648 $m^2$ $nmi^{-2}$, is the highest estimate ever recorded within the time-series (**Figure 16**). Such a sharp increase in acoustic energy may be the result of the combination of several facts, namely, a very high NASC allocated to sardine because the occurrence during this survey of very dense schools in coastal (20-40 m) waters in the central part of the Gulf (see **Annex** figures); a very high NASC allocated to anchovy (mainly in Spanish waters) and chub mackerel (in Portuguese ones); and the high acoustic detection of pearlside in the shelf break, not detected in previous surveys, when its occurrence was occasional and detected in the shallow waters of the upper slope, but not penetrating in the deepest survey limit at 200 m depth.

The current anchovy biomass estimate (34 908 t) becomes in the second historical maximum within the time-series (2006: 35 539 t; 2016: 34 184 t; see **Figure 31**) and denotes a strong increase in relation to the previous year, up to levels well above the historical average (ca. 22 kt), but without showing any clear recent trend. Although the spring *PELAGO 18* survey also estimated increased population levels, such increase was not so pronounced as the estimated by its summer counterpart.

The estimates of Gulf of Cadiz sardine abundance and biomass in summer 2018 were 7 955 million fish and 114 631 t, the historical maximum record in terms of abundance and the second maximum in biomass (the historical maximum was reached in 2006: 123 849 t; see **Figure 31**). As described above, such an increasing trend seems to be the result of a greater availability of the species to the survey, with the occurrence of many dense schools in the shallowest limits of the surveyed area not usually recorded in the most recent years. In any case, these estimates should be analysed in more depth and compared with those ones provided by the Portuguese spring *PELAGO* survey in a standardisation exercise of echograms scrutiny.

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Unión Europea
Fondo Europeo Marítimo y de Pesca (FEMP)

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**Table 1.** *ECOCADIZ 2018-07 s*urvey. Descriptive characteristics of the acoustic tracks.

| Acoustic Track | Location | Date | Start | | | | End | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Latitude | Longitude | UTC time | Mean depth (m) | Latitude | Longitude | UTC time | Mean depth (m) |
| **R01** | Trafalgar | 01/08/18 | 36º 12,968' N | 06º 08,805' W | 06:22 | 24 | 36º 02,075' N | 06º 28,864' W | 08:29 | 240 |
| **R02** | Sancti-Petri | 01/08/18 | 36º 08,505' N | 06º 34,300' W | 09:25 | 210 | 36º 19,420' N | 06º 14,410' W | 16:14 | 28 |
| **R03** | Cádiz | 02/08/18 | 36º 27,223' N | 06º 19,149' W | 06:03 | 26 | 36º 17,589' N | 06º 36,655' W | 09:31 | 222 |
| **R04** | Rota | 02/08/18 | 36º 23,300' N | 06º 42,290' W | 10:31 | 240 | 36º 34,510' N | 06º 23,110' W | 16:24 | 23 |
| **R05** | Chipiona | 03/08/18 | 36º 40,194' N | 06º 29,819' W | 06:00 | 24 | 36º 31,311' N | 06º 46,083' W | 09:34 | 188 |
| **R06** | Doñana | 03/08/18 | 36º 37,740' N | 06º 51,950' W | 10:37 | 177 | 36º 47,050' N | 06º 34,916' W | 14:02 | 19 |
| **R07** | Matalascañas | 04/08/18 | 36º 53,839' N | 06º 40,548' W | 06:01 | 22 | 36º 44,078' N | 06º 58,368' W | 09:43 | 200 |
| **R08** | Mazagón | 04/08/18 | 36º 48,740' N | 07º 07,181' W | 13:44 | 228 | 37º 01,260' N | 06º 44,189' W | 17:18 | 21 |
| **R09** | Punta Umbría | 05/08/18 | 37º 03,767' N | 06º 56,501' W | 06:01 | 29 | 36º 49,549' N | 07º 06,669' W | 09:58 | 210 |
| **R10** | El Rompido | 05/08/18 | 36º 50,130' N | 07º 07,250' W | 12:06 | 165 | 37º 07,233' N | 07º 07,255' W | 17:31 | 21 |
| **R11** | Isla Cristina | 06/08/18 | 37º 07,169' N | 07º 16,685' W | 06:07 | 23 | 36º 53,349' N | 07º 16,699' W | 08:58 | 234 |
| **R12** | V.R. do Sto. Antonio | 06/08/18 | 36º 56,200' N | 07º 26,500' W | 13:39 | 135 | 37º 06,350' N | 07º 26,540' W | 16:25 | 19 |
| **R13** | Tavira | 07/08/18 | 37º 04,820' N | 07º 36,049' W | 05:59 | 21 | 36º 56,959' N | 07º 36,100' W | 08:17 | 216 |
| **R14** | Fuzeta | 07/08/18 | 36º 55,881' N | 07º 45,985' W | 15:34 | 161 | 36º 59,267' N | 07º 46,044' W | 15:54 | 60 |
| **R15** | Cabo Sta. María | 08/08/18 | 36º 55,129' N | 07º 55,978' W | 06:00 | 70 | 36º 52,015' N | 07º 55,999' W | 06:18 | 178 |
| **R16** | Cuarteira | 08/08/18 | 36º 50,130' N | 08º 05,910' W | 11:29 | 202 | 37º 01,389' N | 08º 05,842' W | 14:28 | 20 |
| **R17** | Albufeira | 09/08/18 | 37º 02,494' N | 08º 15,452' W | 06:12 | 29 | 36º 49,338' N | 08º 15,499' W | 09:33 | 204 |
| **R18** | Alfanzina | 09/08/18 | 36º 50,370' N | 08º 25,300' W | 11:43 | 202 | 37º 03,750' N | 08º 25,279' W | 14:49 | 29 |
| **R19** | Portimao | 10/08/18 | 37º 05,785' N | 08º 35,372' W | 06:04 | 27 | 36º 50.381' N | 08º 35,398' W | 09:40 | 202 |
| **R20** | Burgau | 10/08/18 | 36º 52,340' N | 08º 45,002' W | 12:03 | 111 | 37º 03,200' N | 08º 45,000' W | 13:08 | 20 |
| **R21** | Ponta de Sagres | 11/08/18 | 37º 00,038' N | 08º 54,980' W | 06:01 | 23 | 36º 50,790' N | 08º 55,000' W | 08:12 | 202 |

**Table 2.** *ECOCADIZ 2018-07* survey. Descriptive characteristics of the fishing stations.

| FISHING STATION | DATE | POSITION | | | | | | TIMING | | | | TRAWLED DISTANCE (nmi) | ACOUSTIC TRANSECT | ZONE/LANDMARK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | START | | | END | | | START | END | EFFECTIVE TRAWLING | TOTAL MANEOUVRE | | | |
| | | LAT. | LON. | PROF. | LAT. | LON. | PROF. | UTC | UTC | | | | | |
| **PE01** | 01-08-2018 | 36º 16.5388 N | 6º 19.5235 W | 43,4 | 36º 15.1167 N | 6º 22.2324 W | 49,85 | 11:13 | 11:50 | 0:37 | 1:00 | 2,611 | R02 | Sancti-Petri |
| **PE02** | 01-08-2018 | 36º 12.8734 N | 6º 26.3475 W | 81,22 | 36º 11.1748 N | 6º 29.4739 W | 109,27 | 13:20 | 14:03 | 0:42 | 1:11 | 3,046 | R02 | Sancti-Petri |
| **PE03** | 02-08-2018 | 36º 23.8087 N | 6º 25.3450 W | 56,12 | 36º 25.5262 N | 6º 22.1794 W | 45,31 | 07:05 | 07:49 | 0:44 | 1:05 | 3,077 | R03 | Cádiz |
| **PE04** | 02-08-2018 | 36º 23.6157 N | 6º 39.5761 W | 185,48 | 36º 24.7228 N | 6º 40.0975 W | 178,73 | 11:56 | 12:13 | 0:17 | 0:46 | 1,183 | R04 | Rota |
| **PE05** | 02-08-2018 | 36º 29.9443 N | 6º 31.0648 W | 61,33 | 36º 27.5509 N | 6º 35.1775 W | 91,93 | 13:54 | 14:51 | 0:57 | 1:21 | 4,088 | R04 | Rota |
| **PE06** | 03-08-2018 | 36º 33.4984 N | 6º 41.9919 W | 103,93 | 36º 35.0322 N | 6º 39.2943 W | 77,67 | 07:53 | 08:31 | 0:37 | 1:07 | 2,659 | R05 | Chipiona |
| **PE07** | 03-08-2018 | 36º 40.7883 N | 6º 46.3366 W | 93,12 | 36º 39.2739 N | 6º 49.1025 W | 115,33 | 11:37 | 12:15 | 0:37 | 1:02 | 2,69 | R06 | Doñana |
| **PE08** | 03-08-2018 | 36º 43.6651 N | 6º 41.0337 W | 42,56 | 36º 42.1558 N | 6º 43.8061 W | 68,46 | 14:44 | 15:23 | 0:38 | 1:00 | 2,691 | R06 | Doñana |
| **PE09** | 04-08-2018 | 36º 45.7464 N | 6º 55.4163 W | 115,32 | 36º 47.5804 N | 6º 51.7888 W | 89,78 | 07:54 | 8:42 | 0:47 | 1:14 | 3,442 | R07 | Matalascañas |
| **PE10** | 04-08-2018 | 36º 45.3789 N | 6º 56.0539 W | 119,9 | 36º 47.1727 N | 6º 52.6827 W | 95,67 | 11:23 | 12:08 | 0:45 | 1:07 | 3,247 | R07 | Matalascañas |
| **PE11** | 04-08-2018 | 36º 55.9969 N | 6º 50.1088 W | 43,19 | 36º 57.4765 N | 6º 51.7540 W | 43,34 | 15:40 | 16:08 | 0:27 | 0:47 | 1,981 | R08 | Mazagón |
| **PE12** | 05-08-2018 | 36º 57.3658 N | 6º 58.5016 W | 61,49 | 36º 58.9450 N | 7º 01.6909 W | 60,04 | 07:52 | 08:34 | 0:42 | 1:03 | 3,003 | S/D | Sin Datos |
| **PE13** | 05-08-2018 | 36º 55.4889 N | 7º 07.2582 W | 99,23 | 36º 52.2136 N | 7º 07.2657 W | 128,88 | 13:03 | 13:49 | 0:45 | 1:12 | 3,271 | R10 | El Rompido |
| **PE14** | 05-08-2018 | 36º 57.6004 N | 7º 05.9353 W | 82,83 | 36º 58.5603 N | 7º 08.7571 W | 80,93 | 15:41 | 16:16 | 0:34 | 1:00 | 2,456 | R10 | El Rompido |
| **PE15** | 06-08-2018 | 37º 02.2915 N | 7º 14.7397 W | 54,41 | 37º 02.3526 N | 7º 16.8729 W | 53,8 | 07:18 | 07:41 | 0:23 | 0:47 | 1,709 | R11 | Isla Cristina |
| **PE16** | 06-08-2018 | 36º 59.6457 N | 7º 26.5813 W | 99,83 | 36º 56.9236 N | 7º 26.4835 W | 131,28 | 14:29 | 15:07 | 0:38 | 1:01 | 2,72 | R12 | Vila Real do Santo Antonio |
| **PE17** | 07-08-2018 | 37º 03.3214 N | 7º 34.7989 W | 52,5 | 37º 02.6311 N | 7º 36.4885 W | 53,06 | 06:55 | 07:16 | 0:21 | 0:50 | 1,518 | R13 | Tavira |
| **PE18** | 07-08-2018 | 36º 57.8928 N | 7º 36.0870 W | 126,24 | 36º 59.0218 N | 7º 36.0957 W | 109,91 | 08:53 | 09:09 | 0:15 | 2:03 | 1,128 | R13 | Tavira |
| **PE19** | 08-08-2018 | 36º 54.7846 N | 7º 56.5828 W | 73,27 | 36º 55.2130 N | 7º 54.2592 W | 77,05 | 07:14 | 07:41 | 0:27 | 0:49 | 1,912 | R15 | Cabo de Santa María |
| **PE20** | 08-08-2018 | 36º 53.4466 N | 8º 05.8354 W | 96,92 | 36º 50.6529 N | 8º 05.8903 W | 123,2 | 12:24 | 13:03 | 0:39 | 1:10 | 2,791 | R16 | Cuarteira |
| **PE21** | 08-08-2018 | 36º 58.7931 N | 8º 06.8914 W | 41,79 | 36º 58.2543 N | 8º 04.7586 W | 41,45 | 15:19 | 15:44 | 0:25 | 0:42 | 1,792 | R16 | Cuarteira |
| **PE22** | 09-08-2018 | 36º 54.9072 N | 8º 15.7515 W | 91,9 | 36º 54.3112 N | 8º 13.7479 W | 91,7 | 08:13 | 08:37 | 0:24 | 0:45 | 1,713 | R17 | Albufeira |
| **PE23** | 09-08-2018 | 36º 54.1354 N | 8º 25.2601 W | 120 | 36º 51.6123 N | 8º 25.2973 W | 135,35 | 12:36 | 13:12 | 0:36 | 1:02 | 2,52 | R18 | Alfanzina |
| **PE24** | 09-08-2018 | 36º 59.8305 N | 8º 24.4468 W | 43,17 | 37º 00.1414 N | 8º 26.8555 W | 46,94 | 15:50 | 16:18 | 0:27 | 0:50 | 1,954 | R18 | Alfanzina |
| **PE25** | 10-08-2018 | 36º 54.4809 N | 8º 35.3532 W | 104,35 | 36º 56.5975 N | 8º 35.3839 W | 78,75 | 08:15 | 08:44 | 0:28 | 1:00 | 2,114 | R19 | Portimao |

**Table 3.** *ECOCADIZ 2018-07* survey. Catches by species in number (upper panel) and weight (in kg, lower panel) from valid fishing stations.

| ABUNDANCE (nº) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fishing station | ANE | PIL | MAS | MAC | HOM | JAA | HMM | BOG | BOC | MAV | SNS | OTHERS SPP | TOTAL |
| 01 | 27 | 490 | 25920 | 0 | 0 | 0 | 119 | 6 | 0 | 0 | 0 | 185 | **26747** |
| 02 | 19266 | 0 | 9887 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 36 | **29191** |
| 03 | 15273 | 8419 | 408 | 1 | 0 | 0 | 25 | 13 | 0 | 0 | 0 | 230 | **24369** |
| 04 | 0 | 0 | 4 | 26 | 0 | 0 | 0 | 0 | 0 | 253693 | 0 | 46 | **253769** |
| 05 | 36523 | 23 | 15335 | 10 | 0 | 0 | 23 | 11 | 0 | 0 | 0 | 117 | **52042** |
| 06 | 29669 | 718 | 8 | 11 | 2 | 8 | 0 | 0 | 0 | 0 | 0 | 116 | **30532** |
| 07 | 48902 | 8105 | 117 | 32 | 5 | 2 | 0 | 0 | 0 | 4 | 0 | 21 | **57188** |
| 08 | 21463 | 228 | 5 | 9 | 0 | 0 | 59 | 7 | 0 | 0 | 0 | 37 | **21808** |
| 09 | 25261 | 4028 | 189 | 21 | 0 | 1 | 0 | 0 | 0 | 6 | 0 | 31 | **29537** |
| 10 | 32494 | 3985 | 452 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | **36933** |
| 11 | 9200 | 4455 | 1 | 23 | 1 | 0 | 49 | 109 | 0 | 0 | 0 | 273 | **14111** |
| 12 | 7699 | 56273 | 5864 | 112 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 4 | **69963** |
| 13 | 68793 | 4563 | 1140 | 45 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 36 | **74578** |
| 14 | 1308 | 318 | 1 | 15 | 11 | 1 | 0 | 0 | 0 | 0 | 0 | 47 | **1701** |
| 15 | 20 | 46472 | 9536 | 15 | 0 | 0 | 0 | 23 | 0 | 0 | 0 | 20 | **56086** |
| 16 | 4576 | 82 | 151 | 22 | 0 | 0 | 0 | 0 | 0 | 19 | 0 | 137 | **4987** |
| 17 | 272 | 39164 | 1100 | 68 | 21 | 1 | 0 | 112 | 0 | 0 | 0 | 72 | **40810** |
| 18 | 2427 | 25 | 228 | 0 | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 31 | **2723** |
| 19 | 410 | 160 | 0 | 0 | 2 | 0 | 0 | 9 | 0 | 0 | 0 | 62 | **643** |
| 20 | 11413 | 65 | 302 | 14 | 160 | 7 | 0 | 67 | 304 | 0 | 15 | 71 | **12418** |
| 21 | 0 | 3000 | 2137 | 0 | 52 | 8 | 0 | 202 | 0 | 0 | 0 | 704 | **6103** |
| 22 | 13629 | 472 | 2673 | 17 | 48 | 3 | 0 | 8 | 0 | 0 | 0 | 41 | **16891** |
| 23 | 21065 | 57 | 578 | 5 | 42 | 6 | 0 | 19 | 0 | 0 | 1 | 29 | **21802** |
| 24 | 0 | 1591 | 3258 | 0 | 8 | 0 | 0 | 48 | 0 | 0 | 0 | 17 | **4922** |
| 25 | 38 | 1283 | 62933 | 3 | 351 | 26 | 0 | 9 | 0 | 0 | 0 | 9 | **64652** |
| **TOTAL** | **369728** | **183976** | **142227** | **452** | **703** | **76** | **275** | **654** | **304** | **253722** | **16** | **2373** | **954506** |

**Table 3.** *ECOCADIZ 2018-07* survey. Cont'd.

| BIOMASS (kg) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fishing station** | **ANE** | **PIL** | **MAS** | **MAC** | **HOM** | **JAA** | **HMM** | **BOG** | **BOC** | **MAV** | **SNS** | **OTHERS SPP** | **TOTAL** |
| **01** | 0,449 | 23,950 | 1386,650 | 0,000 | 0,000 | 0,000 | 20,600 | 0,761 | 0,000 | 0,000 | 0,000 | 29,882 | **1462,292** |
| **02** | 344,300 | 0,000 | 549,900 | 0,282 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 3,809 | **898,291** |
| **03** | 173,727 | 117,273 | 19,590 | 0,334 | 0,000 | 0,000 | 5,086 | 2,296 | 0,000 | 0,000 | 0,000 | 32,878 | **351,184** |
| **04** | 0,000 | 0,000 | 0,269 | 3,140 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 148,661 | 0,000 | 4,746 | **156,816** |
| **05** | 584,022 | 0,302 | 646,427 | 1,703 | 0,000 | 0,000 | 4,285 | 2,144 | 0,000 | 0,000 | 0,000 | 108,574 | **1347,457** |
| **06** | 296,350 | 7,200 | 0,345 | 1,514 | 0,040 | 0,225 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 12,597 | **318,271** |
| **07** | 595,072 | 97,677 | 9,850 | 4,476 | 0,088 | 0,061 | 0,000 | 0,000 | 0,000 | 0,009 | 0,000 | 1,633 | **708,866** |
| **08** | 144,720 | 21,250 | 0,540 | 1,558 | 0,000 | 0,000 | 10,284 | 1,475 | 0,000 | 0,000 | 0,000 | 3,337 | **183,164** |
| **09** | 314,500 | 47,514 | 13,550 | 3,730 | 0,000 | 0,027 | 0,000 | 0,000 | 0,000 | 0,010 | 0,000 | 3,444 | **382,775** |
| **10** | 431,200 | 48,700 | 21,350 | 0,114 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 4,000 | **505,364** |
| **11** | 87,450 | 50,870 | 0,044 | 3,838 | 0,027 | 0,000 | 8,500 | 18,100 | 0,000 | 0,000 | 0,000 | 33,309 | **202,138** |
| **12** | 96,991 | 1793,266 | 265,111 | 20,200 | 0,000 | 0,000 | 0,000 | 1,934 | 0,000 | 0,000 | 0,000 | 1,052 | **2178,554** |
| **13** | 1090,220 | 63,131 | 60,710 | 8,012 | 0,000 | 0,026 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 13,210 | **1235,309** |
| **14** | 17,700 | 6,630 | 0,040 | 3,328 | 0,213 | 0,039 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 6,531 | **34,481** |
| **15** | 0,246 | 1860,916 | 473,984 | 3,360 | 0,000 | 0,000 | 0,000 | 3,150 | 0,000 | 0,000 | 0,000 | 1,795 | **2343,451** |
| **16** | 56,300 | 1,140 | 12,400 | 3,466 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,030 | 0,000 | 15,950 | **89,286** |
| **17** | 3,572 | 2012,077 | 84,041 | 18,100 | 2,212 | 0,156 | 0,000 | 15,150 | 0,000 | 0,000 | 0,000 | 13,142 | **2148,45** |
| **18** | 34,700 | 0,582 | 17,900 | 0,000 | 0,000 | 0,353 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 5,200 | **58,735** |
| **19** | 5,610 | 2,492 | 0,000 | 0,000 | 0,236 | 0,000 | 0,000 | 1,250 | 0,000 | 0,000 | 0,000 | 10,625 | **20,213** |
| **20** | 187,750 | 1,143 | 24,850 | 2,223 | 23,312 | 0,887 | 0,000 | 8,700 | 1,375 | 0,000 | 0,052 | 7,264 | **257,556** |
| **21** | 0,000 | 119,350 | 136,850 | 0,000 | 4,340 | 0,225 | 0,000 | 19,150 | 0,000 | 0,000 | 0,000 | 102,678 | **382,593** |
| **22** | 306,100 | 9,650 | 166,800 | 3,966 | 6,218 | 0,073 | 0,000 | 0,836 | 0,000 | 0,000 | 0,000 | 5,085 | **498,728** |
| **23** | 551,600 | 1,439 | 51,650 | 0,836 | 4,967 | 0,506 | 0,000 | 2,632 | 0,000 | 0,000 | 0,004 | 3,634 | **617,268** |
| **24** | 0,000 | 77,850 | 145,100 | 0,000 | 0,625 | 0,000 | 0,000 | 4,007 | 0,000 | 0,000 | 0,000 | 1,279 | **228,861** |
| **25** | 0,860 | 61,083 | 3791,030 | 0,778 | 32,681 | 2,723 | 0,000 | 0,856 | 0,000 | 0,000 | 0,000 | 0,856 | **3890,867** |
| **TOTAL** | **5323,439** | **6425,485** | **7878,981** | **84,958** | **74,959** | **5,301** | **48,755** | **82,441** | **1,375** | **148,710** | **0,056** | **426,510** | **20500,970** |

**Table 4.** *ECOCADIZ 2018-07* survey. Parameters of the size-weight relationships for survey's target species. FAO codes for the species: ANE: *Engraulis encrasicolus*; PIL: *Sardina pilchardus*; MAS: *Scomber colias*; MAC: *Scomber scombrus*; HOM: *Trachurus trachurus*; JAA: *Trachurus picturatus;* HMM: *Trachurus mediterraneus*; BOG: *Boops boops*; BOC: *Capros aper*; SNS: *Macrorhamphosus scolopax*; MAV: *Maurolicus muelleri*.

| PARAMETER | ANE | PIL | MAS | MAC | HOM | JAA | HMM | BOG | BOC | SNS | MAV |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Size range (mm) | 93-182 | 98-198 | 157-283 | 247-355 | 111-267 | 115-277 | 224-366 | 181-313 | 47-70 | 78-99 | 35-66 |
| n | 1028 | 1223 | 970 | 402 | 283 | 58 | 189 | 358 | 110 | 15 | 238 |
| a | 0,002053 | 0,001571 | 0,001545 | 0,000313 | 0,005194 | 0,002359 | 0,044915 | 0,009061 | 0,018507 | 0,002166 | 0,006447 |
| b | 3,447416 | 3,608874 | 3,515858 | 3,943451 | 3,169538 | 3,423360 | 2,468256 | 3,010727 | 3,068089 | 3,410636 | 3,090835 |
| $r^2$ | 0,97 | 0,98 | 0,97 | 0,93 | 0,99 | 0,99 | 0,93 | 0,95 | 0,93 | 0,87 | 0,97 |

**Table 5.** *ECOCADIZ 2018-07* survey. Anchovy (*E. encrasicolus*). Estimated abundance (absolute numbers and million fish) and biomass (t) by size class (in cm). Polygons (*i.e.*, coherent or homogeneous post-strata) numbered as in **Figure 17**.

| ***ECOCADIZ 2018-07 . Engraulis encrasicolus* . ABUNDANCE (in numbers and million fish)** | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Size class** | **POL01** | **POL02** | **POL03** | **POL04** | **POL05** | **POL06** | **POL07** | **POL08** | **POL09** | **POL10** | **POL11** | **POL12** | ***n*** | | | **Millions** | | |
| | | | | | | | | | | | | | **PORTUGAL** | **SPAIN** | **TOTAL** | **PORTUGAL** | **SPAIN** | **TOTAL** |
| **6** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **6,5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **7** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **7,5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **8** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **8,5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **9** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3092703 | 0 | 0 | 0 | 3092703 | 3092703 | 0 | 3 | 3 |
| **9,5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24643444 | 0 | 0 | 0 | 24643444 | 24643444 | 0 | 25 | 25 |
| **10** | 0 | 0 | 0 | 0 | 0 | 0 | 805120 | 0 | 7495873 | 248690533 | 0 | 0 | 0 | 256991526 | 256991526 | 0 | 257 | 257 |
| **10,5** | 0 | 0 | 0 | 279874 | 0 | 0 | 4842219 | 273907 | 18776791 | 238778047 | 2845438 | 1142264 | 279874 | 266658666 | 266938540 | 0,3 | 267 | 267 |
| **11** | 0 | 0 | 0 | 0 | 1695995 | 1425718 | 23197540 | 3933829 | 142570020 | 287493489 | 59691670 | 5032808 | 3121713 | 521919356 | 525041069 | 3 | 522 | 525 |
| **11,5** | 0 | 0 | 0 | 373165 | 3502507 | 6790532 | 43635623 | 11221744 | 210107094 | 137739025 | 162033647 | 7426674 | 10666204 | 572163807 | 582830011 | 11 | 572 | 583 |
| **12** | 0 | 0 | 0 | 2636920 | 5649342 | 16094442 | 88777424 | 28770876 | 232594712 | 88787017 | 142115578 | 22451378 | 24380704 | 603496985 | 627877689 | 24 | 603 | 628 |
| **12,5** | 0 | 86228 | 0 | 8144470 | 2838486 | 19680783 | 42357980 | 18970712 | 48760283 | 15288697 | 56846231 | 17624068 | 30749967 | 199847971 | 230597938 | 31 | 200 | 231 |
| **13** | 0 | 1976512 | 0 | 14875864 | 836649 | 15021479 | 40522176 | 15532654 | 14991746 | 6129396 | 45495746 | 52734027 | 32710504 | 175405745 | 208116249 | 33 | 175 | 208 |
| **13,5** | 309445 | 4381698 | 506320 | 7101674 | 167695 | 4644606 | 28152542 | 7475060 | 7495873 | 0 | 5690877 | 33297682 | 17111438 | 82112034 | 99223472 | 17 | 82 | 99 |
| **14** | 1856669 | 10049423 | 3037919 | 3130785 | 389462 | 2866133 | 12482417 | 6943991 | 0 | 0 | 2845438 | 38401012 | 21330391 | 60672858 | 82003249 | 21 | 61 | 82 |
| **14,5** | 5413390 | 5061003 | 8857496 | 466938 | 0 | 352755 | 4111361 | 4889397 | 0 | 3036693 | 0 | 25449273 | 20151582 | 37486724 | 57638306 | 20 | 37 | 58 |
| **15** | 8043039 | 8249726 | 13160181 | 746812 | 0 | 352755 | 1648760 | 1191053 | 0 | 0 | 0 | 9750018 | 30552513 | 12589831 | 43142344 | 31 | 13 | 43 |
| **15,5** | 5259299 | 2491415 | 8605370 | 351044 | 0 | 0 | 0 | 730000 | 0 | 0 | 0 | 5190226 | 16707128 | 5920226 | 22627354 | 17 | 6 | 23 |
| **16** | 4021520 | 771123 | 6580091 | 117574 | 0 | 0 | 0 | 499474 | 0 | 0 | 0 | 8472777 | 11490308 | 8972251 | 20462559 | 11 | 9 | 20 |
| **16,5** | 928334 | 428675 | 1518959 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3378713 | 2875968 | 3378713 | 6254681 | 3 | 3 | 6 |
| **17** | 772981 | 86228 | 1264766 | 117574 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3378713 | 2241549 | 3378713 | 5620262 | 2 | 3 | 6 |
| **17,5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **18** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **18,5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TOTAL *n*** | 26604677 | 33582031 | 43531102 | 38342694 | 15080136 | 67229203 | 290533162 | 100432697 | 682792392 | 1053679044 | 477564625 | 233729633 | 224369843 | 2838731553 | 3063101396 | **224** | **2839** | **3063** |
| **Millions** | **27** | **34** | **44** | **38** | **15** | **67** | **291** | **100** | **683** | **1054** | **478** | **234** | | | | | | |

**Table 5.** *ECOCADIZ 2018-07* survey. Anchovy (*E. encrasicolus*). Cont'd.

| *ECOCADIZ 2018-07 . Engraulis encrasicolus* . BIOMASS (t) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Size class** | **POL01** | **POL02** | **POL03** | **POL04** | **POL05** | **POL06** | **POL07** | **POL08** | **POL09** | **POL10** | **POL11** | **POL12** | **PORTUGAL** | **SPAIN** | **TOTAL** |
| **6** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** |
| **6,5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** |
| **7** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** |
| **7,5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** |
| **8** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** |
| **8,5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** |
| **9** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13,596 | 0 | 0 | **0** | **13,596** | **13,596** |
| **9,5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 129,897 | 0 | 0 | **0** | **129,897** | **129,897** |
| **10** | 0 | 0 | 0 | 0 | 0 | 0 | 5,042 | 0 | 46,946 | 1557,512 | 0 | 0 | **0** | **1609,500** | **1609,500** |
| **10,5** | 0 | 0 | 0 | 2,066 | 0 | 0 | 35,738 | 2,022 | 138,58 | 1762,28 | 21,000 | 8,430 | **2,066** | **1968,050** | **1970,116** |
| **11** | 0 | 0 | 0 | 0 | 14,641 | 12,308 | 200,257 | 33,96 | 1230,764 | 2481,844 | 515,300 | 43,447 | **26,949** | **4505,572** | **4532,521** |
| **11,5** | 0 | 0 | 0 | 3,742 | 35,126 | 68,101 | 437,616 | 112,541 | 2107,137 | 1381,367 | 1625,015 | 74,481 | **106,969** | **5738,157** | **5845,126** |
| **12** | 0 | 0 | 0 | 30,531 | 65,410 | 186,346 | 1027,89 | 333,117 | 2693,047 | 1028,001 | 1645,454 | 259,948 | **282,287** | **6987,457** | **7269,744** |
| **12,5** | 0 | 1,146 | 0 | 108,244 | 37,725 | 261,567 | 562,957 | 252,129 | 648,046 | 203,194 | 755,512 | 234,232 | **408,682** | **2656,070** | **3064,752** |
| **13** | 0 | 29,994 | 0 | 225,743 | 12,696 | 227,952 | 614,928 | 235,709 | 227,501 | 93,014 | 690,402 | 800,244 | **496,385** | **2661,798** | **3158,183** |
| **13,5** | 5,335 | 75,550 | 8,730 | 122,448 | 2,891 | 80,083 | 485,408 | 128,885 | 129,244 | 0 | 98,122 | 574,121 | **295,037** | **1415,780** | **1710,817** |
| **14** | 36,208 | 195,978 | 59,244 | 61,055 | 7,595 | 55,894 | 243,425 | 135,418 | 0 | 0 | 55,490 | 748,874 | **415,974** | **1183,207** | **1599,181** |
| **14,5** | 118,896 | 111,157 | 194,540 | 10,256 | 0 | 7,748 | 90,299 | 107,388 | 0 | 66,696 | 0 | 558,951 | **442,597** | **823,334** | **1265,931** |
| **15** | 198,166 | 203,259 | 324,244 | 18,40 | 0 | 8,691 | 40,623 | 29,345 | 0 | 0 | 0 | 240,223 | **752,760** | **310,191** | **1062,951** |
| **15,5** | 144,823 | 68,605 | 236,963 | 9,667 | 0 | 0 | 0 | 20,102 | 0 | 0 | 0 | 142,921 | **460,058** | **163,023** | **623,081** |
| **16** | 123,337 | 23,650 | 201,806 | 3,606 | 0 | 0 | 0 | 15,318 | 0 | 0 | 0 | 259,853 | **352,399** | **275,171** | **627,570** |
| **16,5** | 31,607 | 14,595 | 51,715 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 115,034 | **97,917** | **115,034** | **212,951** |
| **17** | 29,126 | 3,249 | 47,657 | 4,430 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 127,310 | **84,462** | **127,310** | **211,772** |
| **17,5** | | | | | | | | | | | | | **0** | **0** | **0** |
| **18** | | | | | | | | | | | | | **0** | **0** | **0** |
| **18,5** | | | | | | | | | | | | | **0** | **0** | **0** |
| **TOTAL** | **687,498** | **727,183** | **1124,899** | **600,188** | **176,084** | **908,690** | **3744,183** | **1405,934** | **7221,265** | **8717,401** | **5406,295** | **4188,069** | **4224,542** | **30683,147** | **34907,689** |

**Table 6.** *ECOCADIZ 2018-07* survey. Anchovy (*E. encrasicolus*). Estimated abundance (thousands of individuals) and biomass (tonnes) by age group. Polygons (*i.e.*, coherent or homogeneous post-strata) numbered as in **Figure 17** and ordered from west to east.

| Age class | POL01 | POL02 | POL03 | POL04 | POL05 | POL06 | POL07 | POL08 | POL09 | POL10 | POL11 | POL12 | PT | ES | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | N | N | N | N | N | Nr | N | N | N | N | N | N | N | N |
| 0 | 135 | 705 | 221 | 4185 | 4686 | 12540 | 75088 | 19756 | 292222 | 804922 | 169500 | 24026 | 22472 | 1385513 | 1407986 |
| I | 21702 | 30463 | 35509 | 33232 | 10272 | 53845 | 211646 | 78746 | 386744 | 247267 | 304962 | 194840 | 185024 | 1424206 | 1609230 |
| II | 4767 | 2414 | 7801 | 926 | 122 | 844 | 3800 | 1931 | 3826 | 1490 | 3102 | 14863 | 16874 | 29012 | 45886 |
| III | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 26605 | 33582 | 43531 | 38343 | 15080 | 67229 | 290533 | 100433 | 682792 | 1053679 | 477565 | 233730 | 224370 | 2838732 | 3063101 |

| Age class | POL01 | POL02 | POL03 | POL04 | POL05 | POL06 | POL07 | POL08 | POL09 | POL10 | POL11 | POL12 | PT | ES | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B |
| 0 | 3 | 12 | 5 | 57 | 49 | 149 | 800 | 225 | 2818 | 6150 | 1731 | 301 | 276 | 12024 | 12299 |
| I | 542 | 653 | 887 | 524 | 125 | 746 | 2885 | 1143 | 4356 | 2549 | 3635 | 3479 | 3479 | 18047 | 21526 |
| II | 142 | 62 | 233 | 19 | 2 | 13 | 60 | 37 | 47 | 19 | 41 | 409 | 470 | 613 | 1083 |
| III | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 688 | 727 | 1125 | 600 | 176 | 909 | 3744 | 1406 | 7221 | 8717 | 5406 | 4188 | 4225 | 30683 | 34908 |

**Table 7.** *ECOCADIZ 2018-07* survey. Sardine (*S. pilchardus*). Estimated abundance (absolute numbers and million fish) and biomass (t) by size class (in cm). Polygons (*i.e.*, coherent or homogeneous post-strata) numbered as in **Figure 21**.

***ECOCADIZ 2018-07 . Sardina pilchardus* . ABUNDANCE (in numbers and million fish)**

| Size class | POL01 | POL02 | POL03 | POL04 | POL05 | POL06 | POL07 | POL08 | POL09 | POL10 | POL11 | POL12 | POL13 | POL14 | *n* | | | Millions | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | PORTUGAL | SPAIN | TOTAL | PORTUGAL | SPAIN | TOTAL |
| **6** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **6,5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **7** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **7,5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **8** | 0 | 0 | 0 | 0 | 0 | 762681 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 762681 | 0 | 762681 | 1 | 0 | 1 |
| **8,5** | 0 | 0 | 0 | 0 | 0 | 762681 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 762681 | 0 | 762681 | 1 | 0 | 1 |
| **9** | 0 | 0 | 0 | 0 | 0 | 2288043 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2288043 | 0 | 2288043 | 2 | 0 | 2 |
| **9,5** | 0 | 0 | 0 | 0 | 0 | 26693832 | 0 | 0 | 0 | 0 | 0 | 6208375 | 22645897 | 0 | 26693832 | 28854272 | 55548104 | 27 | 29 | 56 |
| **10** | 0 | 0 | 0 | 0 | 2300 | 11440214 | 0 | 0 | 0 | 0 | 62070 | 49127140 | 118366037 | 0 | 11442514 | 167555247 | 178997761 | 11 | 168 | 179 |
| **10,5** | 0 | 0 | 0 | 0 | 9199 | 7626809 | 0 | 0 | 0 | 0 | 62070 | 185130871 | 388409046 | 0 | 7636008 | 573601987 | 581237995 | 8 | 574 | 581 |
| **11** | 0 | 0 | 0 | 0 | 9199 | 2288043 | 70670 | 2812518 | 0 | 901486 | 248278 | 833809930 | 911089263 | 0 | 5180430 | 1746048957 | 1751229387 | 5 | 1746 | 1751 |
| **11,5** | 0 | 0 | 1415804 | 0 | 11499 | 7626809 | 610331 | 2625017 | 1529007 | 4885678 | 1179323 | 1343572214 | 478386991 | 0 | 12289460 | 1829553213 | 1841842673 | 12 | 1830 | 1842 |
| **12** | 0 | 0 | 1415804 | 0 | 9199 | 5338766 | 1002227 | 4875032 | 11082956 | 4520040 | 1303462 | 1303507414 | 209844468 | 8254 | 12641028 | 1530266594 | 1542907622 | 13 | 1530 | 1543 |
| **12,5** | 1351 | 319070 | 4601364 | 2950 | 16098 | 6864128 | 1149991 | 2812518 | 12841380 | 6694955 | 2048297 | 749698288 | 60446836 | 0 | 15767470 | 831729756 | 847497226 | 16 | 832 | 847 |
| **13** | 1351 | 413563 | 12034338 | 2950 | 27597 | 11440214 | 1291331 | 1687511 | 19261163 | 7419927 | 2917272 | 234898989 | 4644563 | 8254 | 26898855 | 269150168 | 296049023 | 27 | 269 | 296 |
| **13,5** | 4052 | 3800270 | 76099490 | 8849 | 22998 | 11440214 | 539661 | 187501 | 8046507 | 3076401 | 1365532 | 77678310 | 3235128 | 8254 | 92103035 | 93410132 | 185513167 | 92 | 93 | 186 |
| **14** | 20259 | 9256076 | 31147698 | 44243 | 13799 | 7626809 | 321227 | 187501 | 3615393 | 901486 | 1489671 | 20170679 | 4644563 | 0 | 48617612 | 30821792 | 79439404 | 49 | 31 | 79 |
| **14,5** | 20259 | 13879593 | 25484480 | 44243 | 18398 | 11440214 | 179887 | 187501 | 1275071 | 359334 | 2110367 | 6338665 | 7879691 | 8254 | 51254575 | 17971382 | 69225957 | 51 | 18 | 69 |
| **15** | 27012 | 13081213 | 7432973 | 58991 | 6899 | 762681 | 109217 | 0 | 849547 | 0 | 3475898 | 0 | 3235128 | 8254 | 21478986 | 7568827 | 29047813 | 21 | 8 | 29 |
| **15,5** | 2701 | 7188060 | 7432973 | 5899 | 0 | 7626809 | 0 | 0 | 7051645 | 0 | 2731063 | 0 | 0 | 105233 | 22256442 | 9887941 | 32144383 | 22 | 10 | 32 |
| **16** | 0 | 6328816 | 0 | 0 | 0 | 0 | 10581205 | 0 | 9041739 | 0 | 620696 | 0 | 0 | 160944 | 16910021 | 9823379 | 26733400 | 17 | 10 | 27 |
| **16,5** | 0 | 13590154 | 0 | 0 | 0 | 0 | 21155986 | 0 | 18084956 | 0 | 0 | 0 | 0 | 328079 | 34746140 | 18413035 | 53159175 | 35 | 18 | 53 |
| **17** | 0 | 28315306 | 0 | 0 | 2300 | 0 | 110322077 | 0 | 35798430 | 0 | 0 | 0 | 0 | 191895 | 138639683 | 35990325 | 174630008 | 139 | 36 | 175 |
| **17,5** | 0 | 28701776 | 0 | 0 | 0 | 0 | 68003680 | 0 | 25549634 | 0 | 0 | 0 | 0 | 96979 | 96705456 | 25646613 | 122352069 | 97 | 26 | 122 |
| **18** | 0 | 23156153 | 0 | 0 | 0 | 0 | 31737192 | 0 | 9748444 | 0 | 0 | 0 | 0 | 33014 | 54893345 | 9781458 | 64674803 | 55 | 10 | 65 |
| **18,5** | 0 | 7316354 | 0 | 0 | 0 | 0 | 4535720 | 0 | 1446401 | 0 | 0 | 0 | 0 | 24761 | 11852074 | 1471162 | 13323236 | 12 | 1 | 13 |
| **19** | 0 | 2927936 | 0 | 0 | 0 | 0 | 0 | 0 | 1059163 | 0 | 0 | 0 | 0 | 8254 | 2927936 | 1067417 | 3995353 | 3 | 1 | 4 |
| **19,5** | 0 | 319070 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16507 | 319070 | 16507 | 335577 | 0,3 | 0,02 | 0,3 |
| **20** | 0 | 567837 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 567837 | 0 | 567837 | 1 | 0 | 1 |
| **20,5** | 0 | 267217 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8254 | 267217 | 8254 | 275471 | 0,3 | 0,01 | 0,3 |
| **21** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **21,5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TOTAL *n*** | 76985 | 159428464 | 167064924 | 168125 | 149485 | 122028947 | 251610402 | 15375099 | 166281436 | 28759307 | 19613999 | 4810140875 | 2212827611 | 1015190 | 715902431 | 7238638418 | 7954540849 | **716** | **7239** | **7955** |
| **Millions** | **0,1** | **159** | **167** | **0,2** | **0,1** | **122** | **252** | **15** | **166** | **29** | **20** | **4810** | **2213** | **1** | **716** | **7239** | **7955** | | | |

**Table 7.** *ECOCADIZ 2018-07* survey. Sardine (*S. pilchardus*). Cont'd

| *ECOCADIZ 2018-07* . *Sardina pilchardus* . BIOMASS (t) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Size class** | **POL01** | **POL02** | **POL03** | **POL04** | **POL05** | **POL06** | **POL07** | **POL08** | **POL09** | **POL10** | **POL11** | **POL12** | **POL13** | **POL14** | **PORTUGAL** | **SPAIN** | **TOTAL** |
| **6** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** |
| **6,5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** |
| **7** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** |
| **7,5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** |
| **8** | 0 | 0 | 0 | 0 | 0 | 2,431 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **2,431** | **0** | **2,431** |
| **8,5** | 0 | 0 | 0 | 0 | 0 | 3,006 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **3,006** | **0** | **3,006** |
| **9** | 0 | 0 | 0 | 0 | 0 | 11,021 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **11,021** | **0** | **11,021** |
| **9,5** | 0 | 0 | 0 | 0 | 0 | 155,482 | 0 | 0 | 0 | 0 | 0 | 36,162 | 131,904 | 0 | **155,482** | **168,066** | **323,548** |
| **10** | 0 | 0 | 0 | 0 | 0,016 | 79,815 | 0 | 0 | 0 | 0 | 0,433 | 342,746 | 825,806 | 0 | **79,831** | **1168,985** | **1248,816** |
| **10,5** | 0 | 0 | 0 | 0 | 0,076 | 63,189 | 0 | 0 | 0 | 0 | 0,514 | 1533,832 | 3218,017 | 0 | **63,265** | **4752,363** | **4815,628** |
| **11** | 0 | 0 | 0 | 0 | 0,090 | 22,337 | 0,690 | 27,457 | 0 | 8,801 | 2,424 | 8139,914 | 8894,339 | 0 | **50,574** | **17045,478** | **17096,052** |
| **11,5** | 0 | 0 | 16,170 | 0 | 0,131 | 87,106 | 6,971 | 29,981 | 17,463 | 55,800 | 13,469 | 15345,061 | 5463,701 | 0 | **140,359** | **20895,494** | **21035,853** |
| **12** | 0 | 0 | 18,794 | 0 | 0,122 | 70,870 | 13,304 | 64,714 | 147,122 | 60,002 | 17,303 | 17303,554 | 2785,604 | 0,110 | **167,804** | **20313,695** | **20481,499** |
| **12,5** | 0,021 | 4,893 | 70,568 | 0,045 | 0,247 | 105,271 | 17,637 | 43,134 | 196,940 | 102,676 | 31,413 | 11497,654 | 927,035 | 0 | **241,816** | **12755,718** | **12997,534** |
| **13** | 0,024 | 7,287 | 212,048 | 0,052 | 0,486 | 201,579 | 22,754 | 29,734 | 339,386 | 130,741 | 51,403 | 4138,973 | 81,838 | 0,145 | **473,964** | **4742,486** | **5216,45** |
| **13,5** | 0,082 | 76,539 | 1532,67 | 0,178 | 0,463 | 230,410 | 10,869 | 3,776 | 162,059 | 61,960 | 27,502 | 1564,468 | 65,157 | 0,166 | **1854,987** | **1881,312** | **3736,299** |
| **14** | 0,464 | 212,068 | 713,632 | 1,014 | 0,316 | 174,740 | 7,360 | 4,296 | 82,833 | 20,654 | 34,130 | 462,135 | 106,413 | 0 | **1113,89** | **706,165** | **1820,055** |
| **14,5** | 0,526 | 360,144 | 661,264 | 1,148 | 0,477 | 296,847 | 4,668 | 4,865 | 33,085 | 9,324 | 54,759 | 164,474 | 204,460 | 0,214 | **1329,939** | **466,316** | **1796,255** |
| **15** | 0,791 | 382,821 | 217,525 | 1,726 | 0,202 | 22,320 | 3,196 | 0 | 24,862 | 0 | 101,722 | 0 | 94,676 | 0,242 | **628,581** | **221,502** | **850,083** |
| **15,5** | 0,089 | 236,332 | 244,384 | 0,194 | 0 | 250,757 | 0 | 0 | 231,847 | 0 | 89,793 | 0 | 0 | 3,460 | **731,756** | **325,1** | **1056,856** |
| **16** | 0 | 232,925 | 0 | 0 | 0 | 0 | 389,429 | 0 | 332,771 | 0 | 22,844 | 0 | 0 | 5,923 | **622,354** | **361,538** | **983,892** |
| **16,5** | 0 | 557,976 | 0 | 0 | 0 | 0 | 868,609 | 0 | 742,521 | 0 | 0 | 0 | 0 | 13,47 | **1426,585** | **755,991** | **2182,576** |
| **17** | 0 | 1292,746 | 0 | 0 | 0,105 | 0 | 5036,795 | 0 | 1634,39 | 0 | 0 | 0 | 0 | 8,761 | **6329,646** | **1643,151** | **7972,797** |
| **17,5** | 0 | 1452,727 | 0 | 0 | 0 | 0 | 3441,975 | 0 | 1293,183 | 0 | 0 | 0 | 0 | 4,909 | **4894,702** | **1298,092** | **6192,794** |
| **18** | 0 | 1295,63 | 0 | 0 | 0 | 0 | 1775,755 | 0 | 545,444 | 0 | 0 | 0 | 0 | 1,847 | **3071,385** | **547,291** | **3618,676** |
| **18,5** | 0 | 451,307 | 0 | 0 | 0 | 0 | 279,784 | 0 | 89,221 | 0 | 0 | 0 | 0 | 1,527 | **731,091** | **90,748** | **821,839** |
| **19** | 0 | 198,603 | 0 | 0 | 0 | 0 | 0 | 0 | 71,843 | 0 | 0 | 0 | 0 | 0,560 | **198,603** | **72,403** | **271,006** |
| **19,5** | 0 | 23,741 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,228 | **23,741** | **1,228** | **24,969** |
| **20** | 0 | 46,241 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **46,241** | **0** | **46,241** |
| **20,5** | 0 | 23,763 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,734 | **23,763** | **0,734** | **24,497** |
| **21** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** |
| **21,5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** |
| **TOTAL** | **1,997** | **6855,743** | **3687,055** | **4,357** | **2,731** | **1777,181** | **11879,796** | **207,957** | **5944,970** | **449,958** | **447,709** | **60528,973** | **22798,95** | **43,296** | **24416,817** | **90213,856** | **114630,673** |

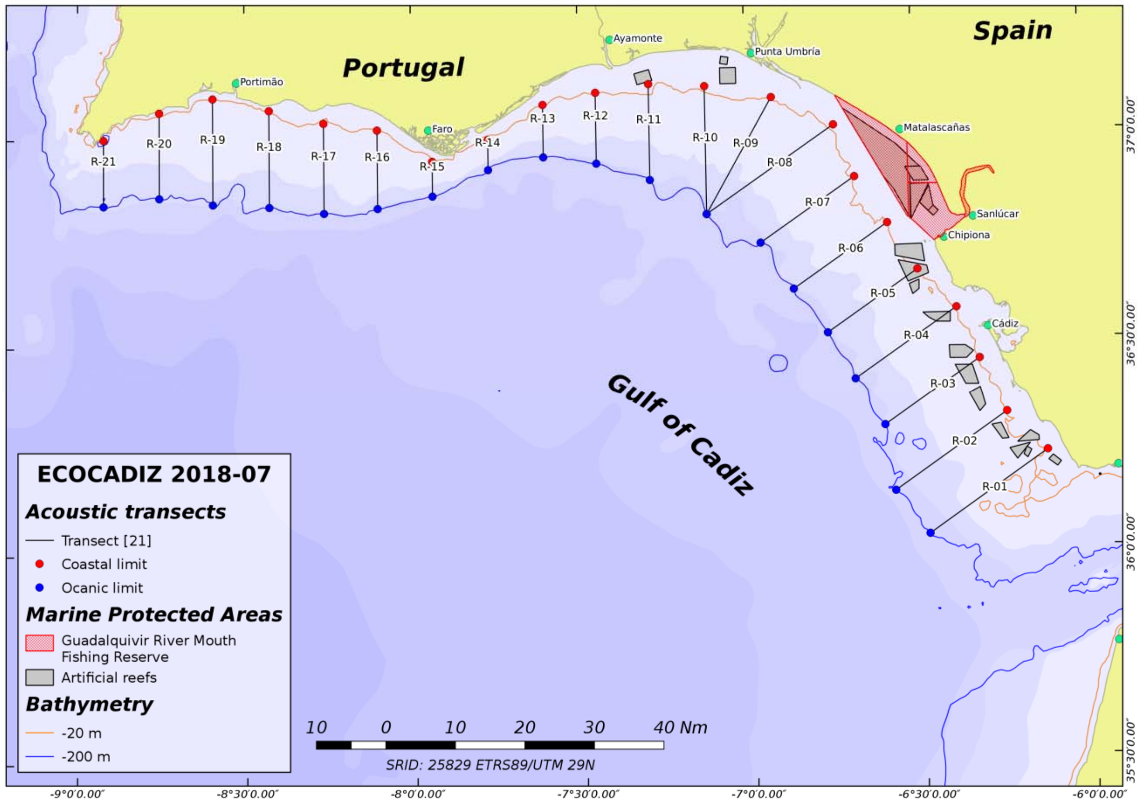



**Figure 1.** *ECOCADIZ 2018-07* survey. Location of the acoustic transects sampled during the survey. The different protected areas inside the Guadalquivir river mouth Fishing Reserve and artificial reef polygons are also shown.

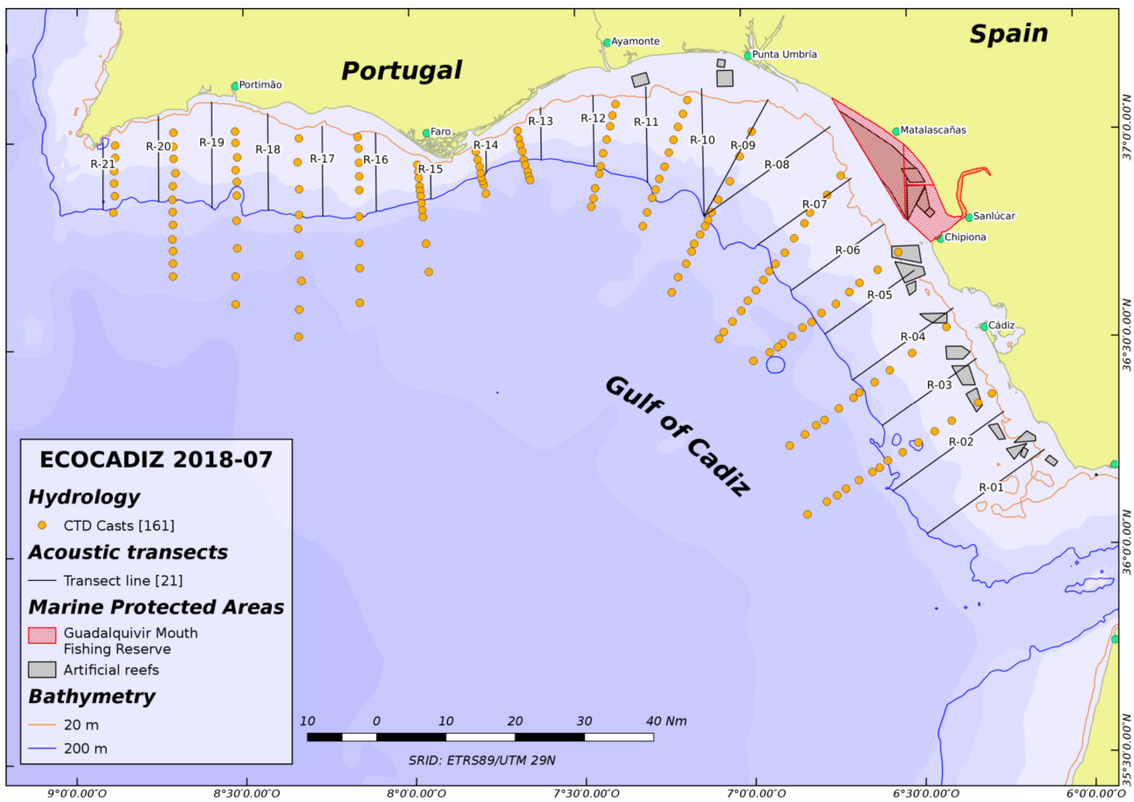



**Figure 2.** *ECOCADIZ 2018-07* survey. Location of CTD-LADCP stations.

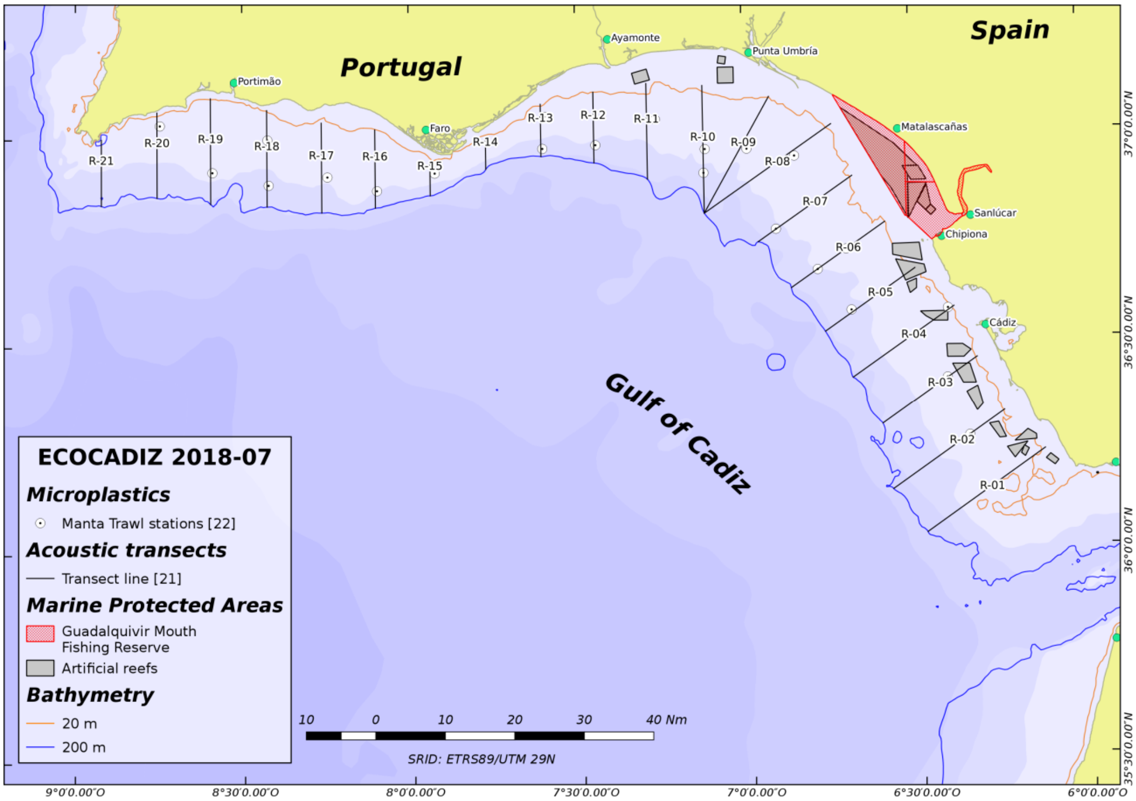



**Figure 3.** *ECOCADIZ 2018-07* survey. Location of Manta trawl hauls (micro-plastics).

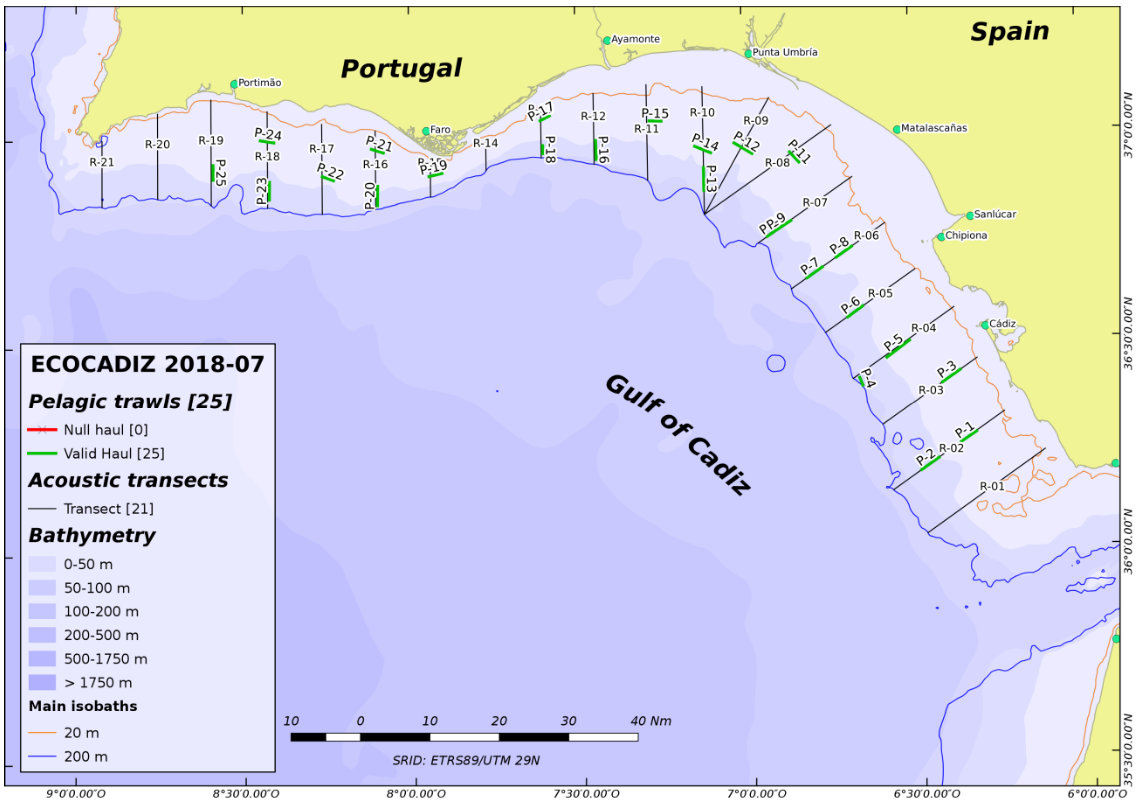



**Figure 4.** *ECOCADIZ 2018-07* survey. Location of ground-truthing fishing hauls.

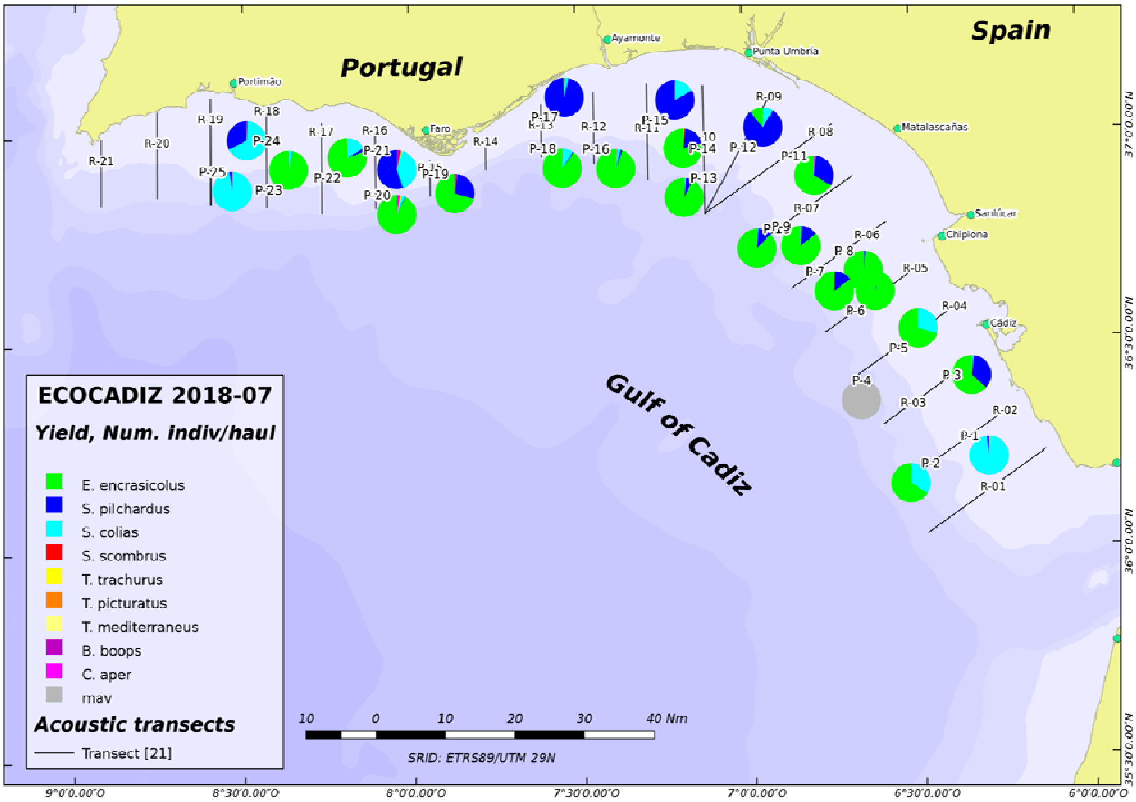



**Figure 5.** *ECOCADIZ 2018-07* survey. Species composition (percentages in number) in fishing hauls.

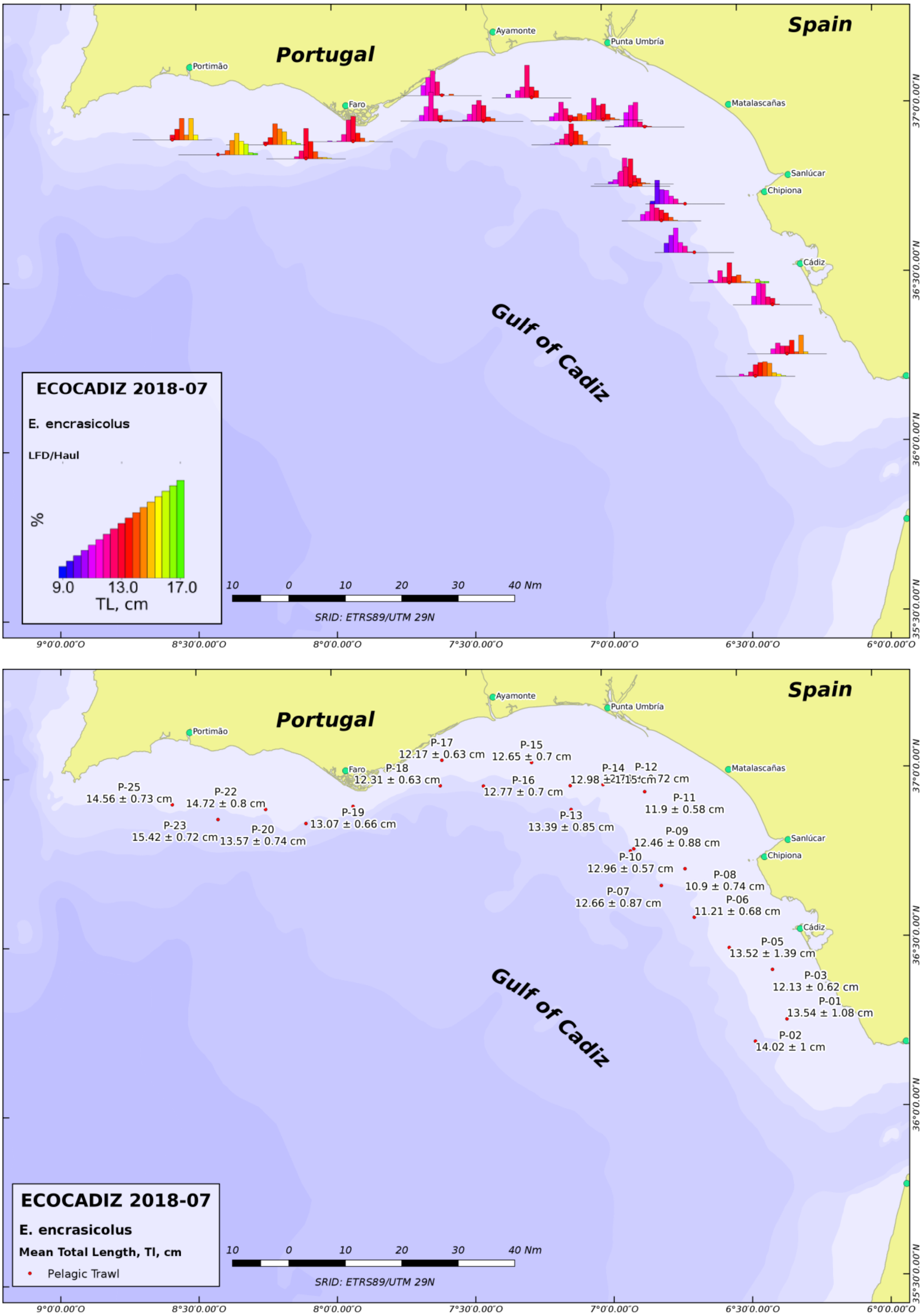



**Figure 6.** *ECOCADIZ 2018-07* survey. *Engraulis encrasicolus*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

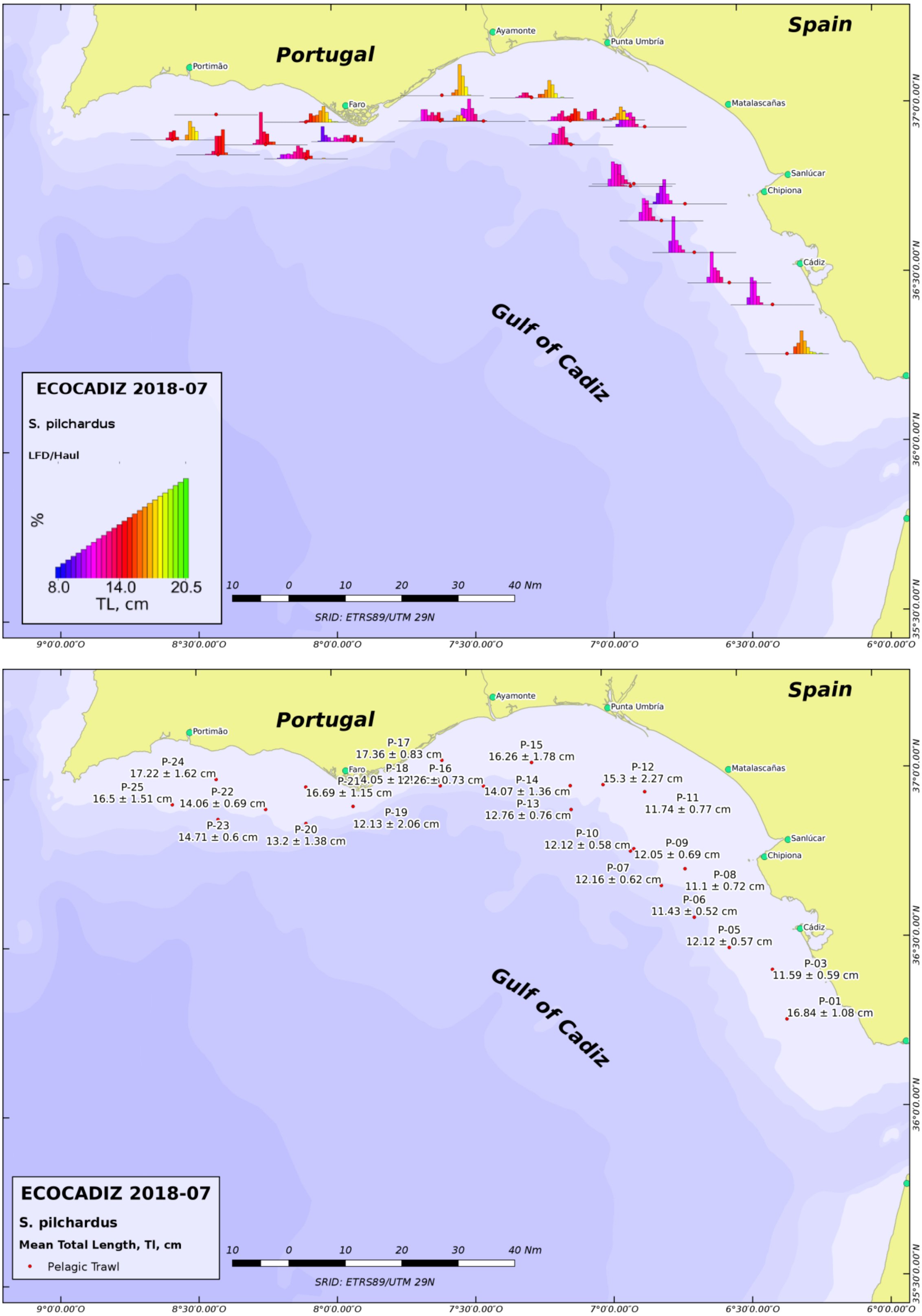



**Figure 7.** *ECOCADIZ 2018-07* survey. *Sardina pilchardus*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

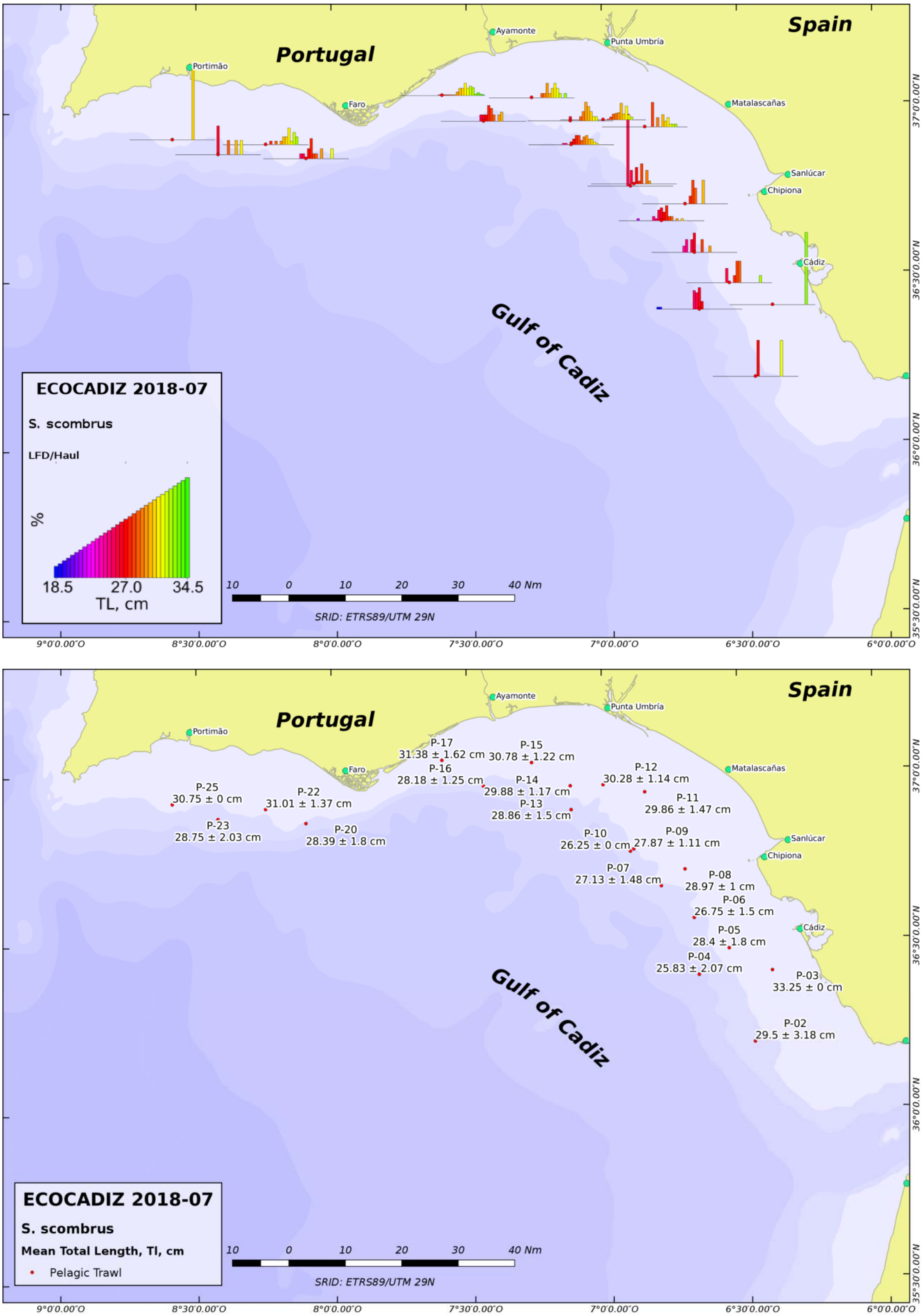



**Figure 8.** *ECOCADIZ 2018-07* survey. *Scomber scombrus*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

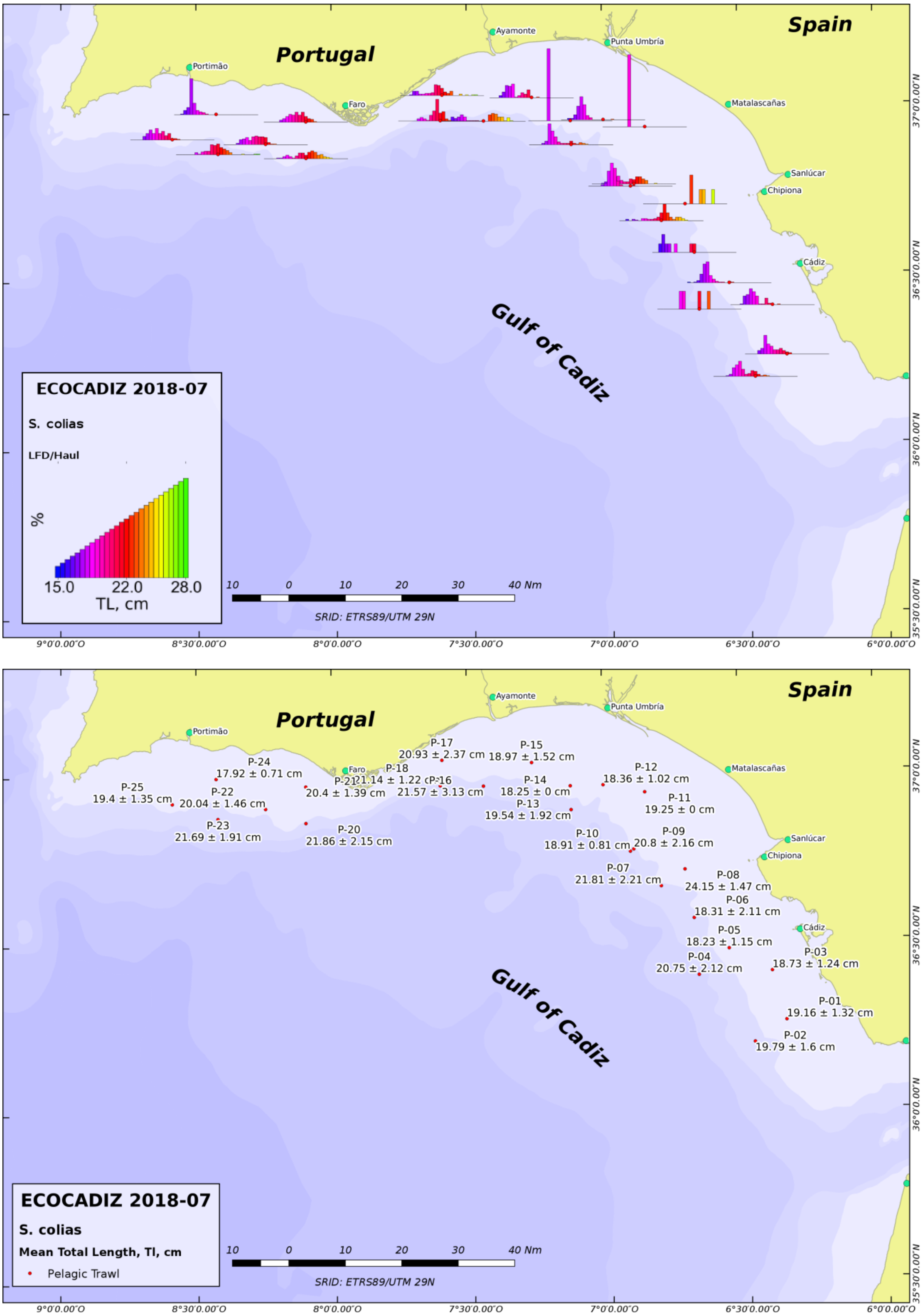



**Figure 9.** *ECOCADIZ 2018-07* survey. *Scomber colias*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

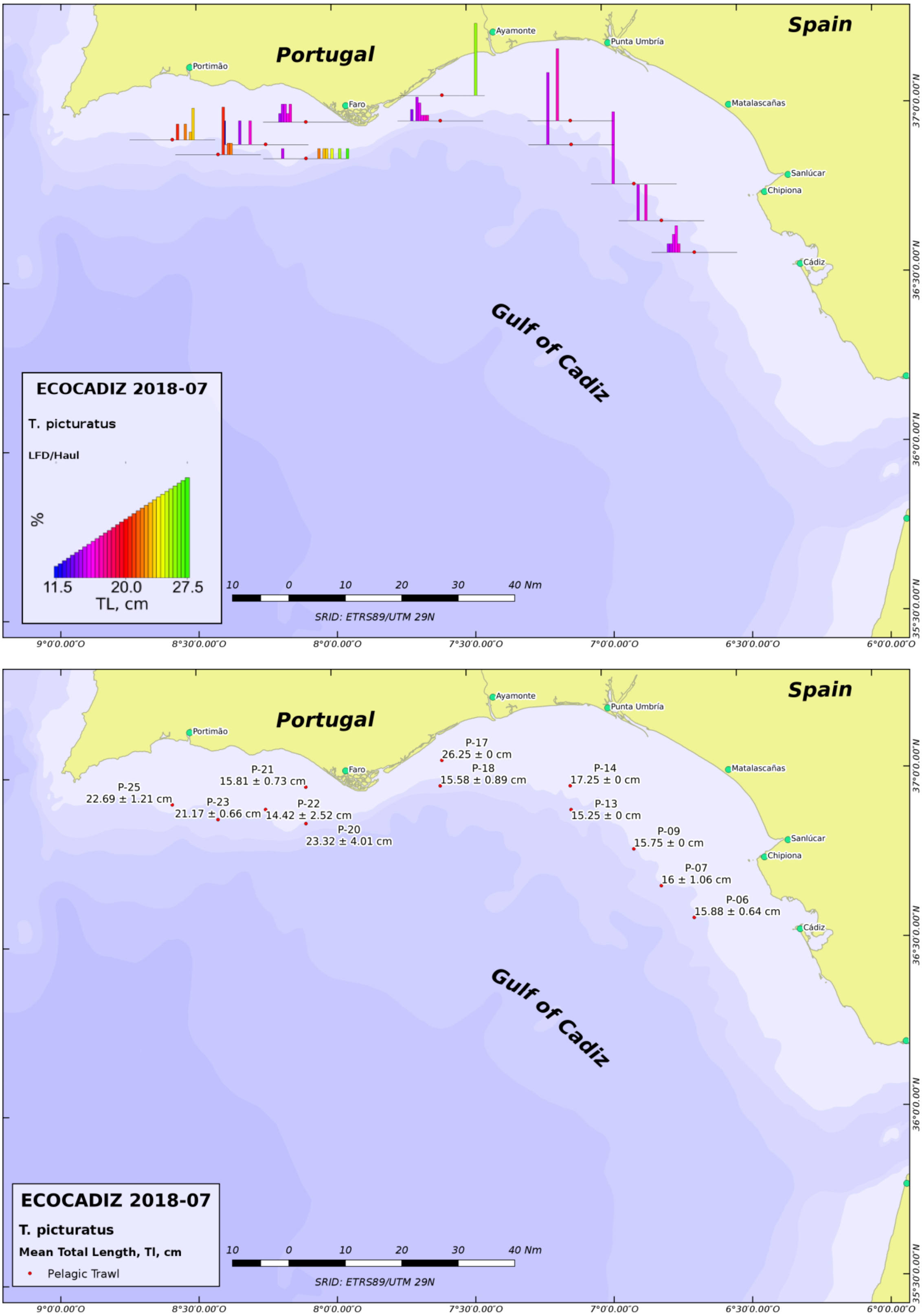



**Figure 10.** *ECOCADIZ 2018-07* survey. *Trachurus picturatus*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

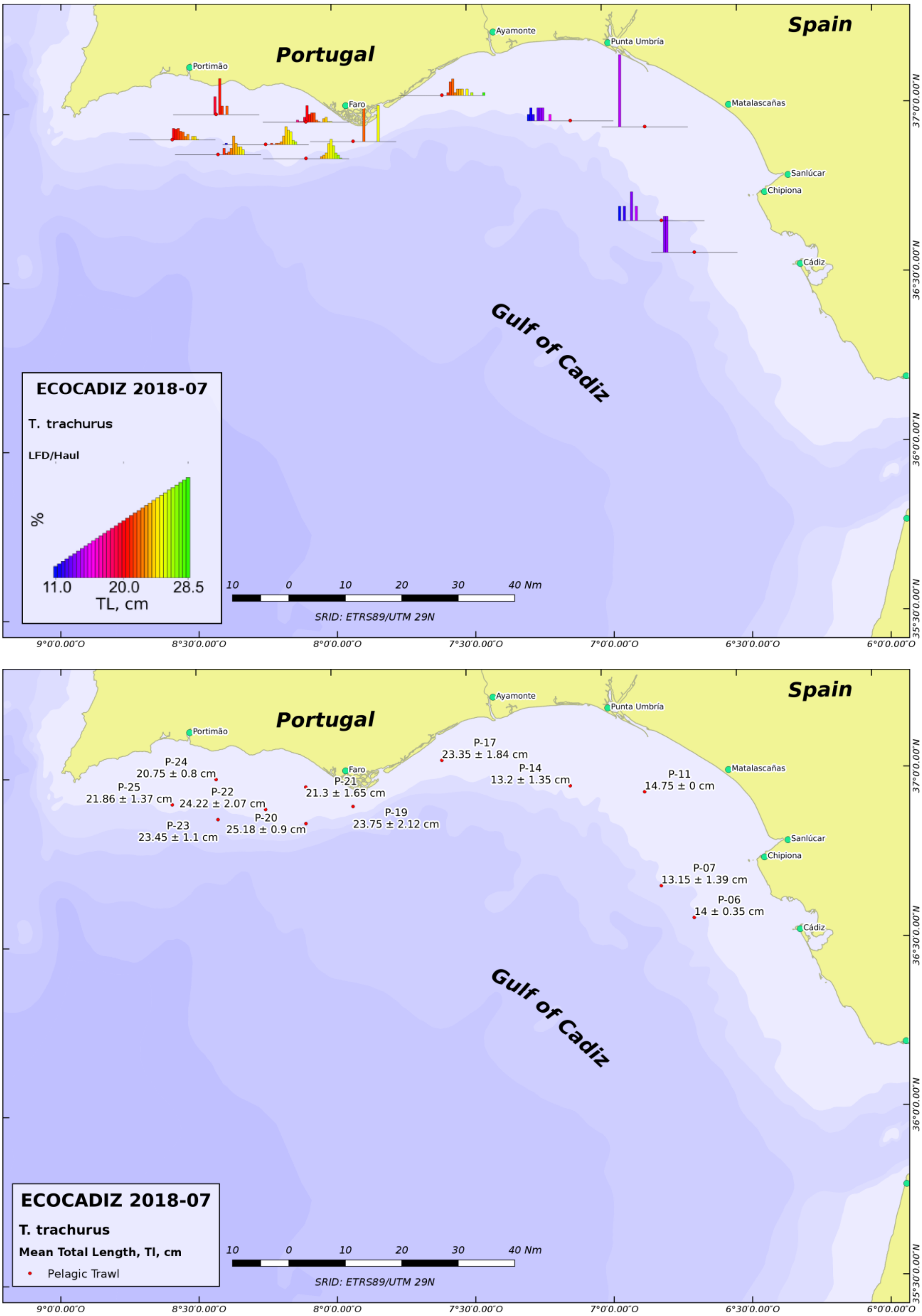



**Figure 11.** *ECOCADIZ 2018-07* survey. *Trachurus trachurus*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

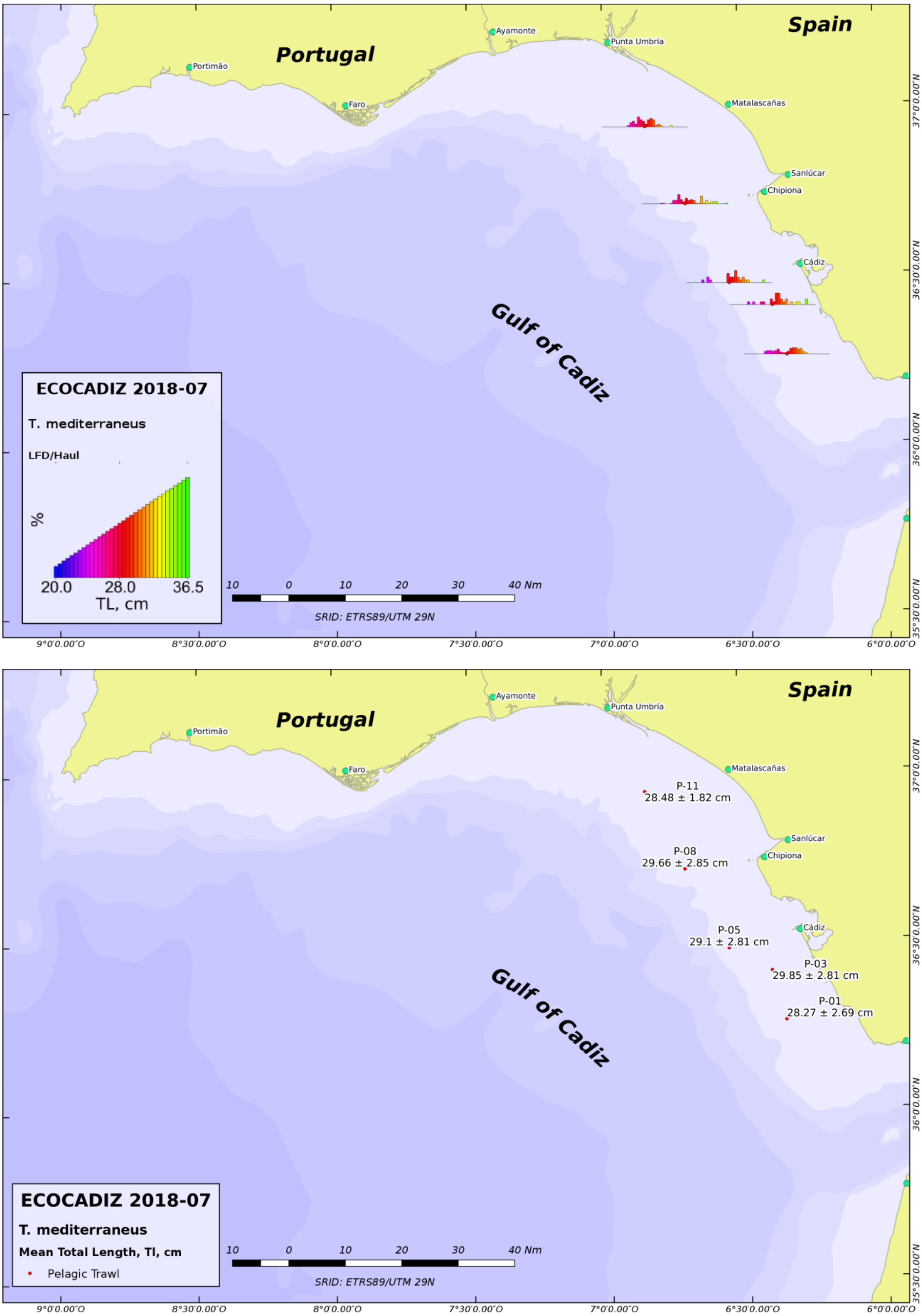



**Figure 12.** *ECOCADIZ 2018-07* survey. *Trachurus mediterraneus*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

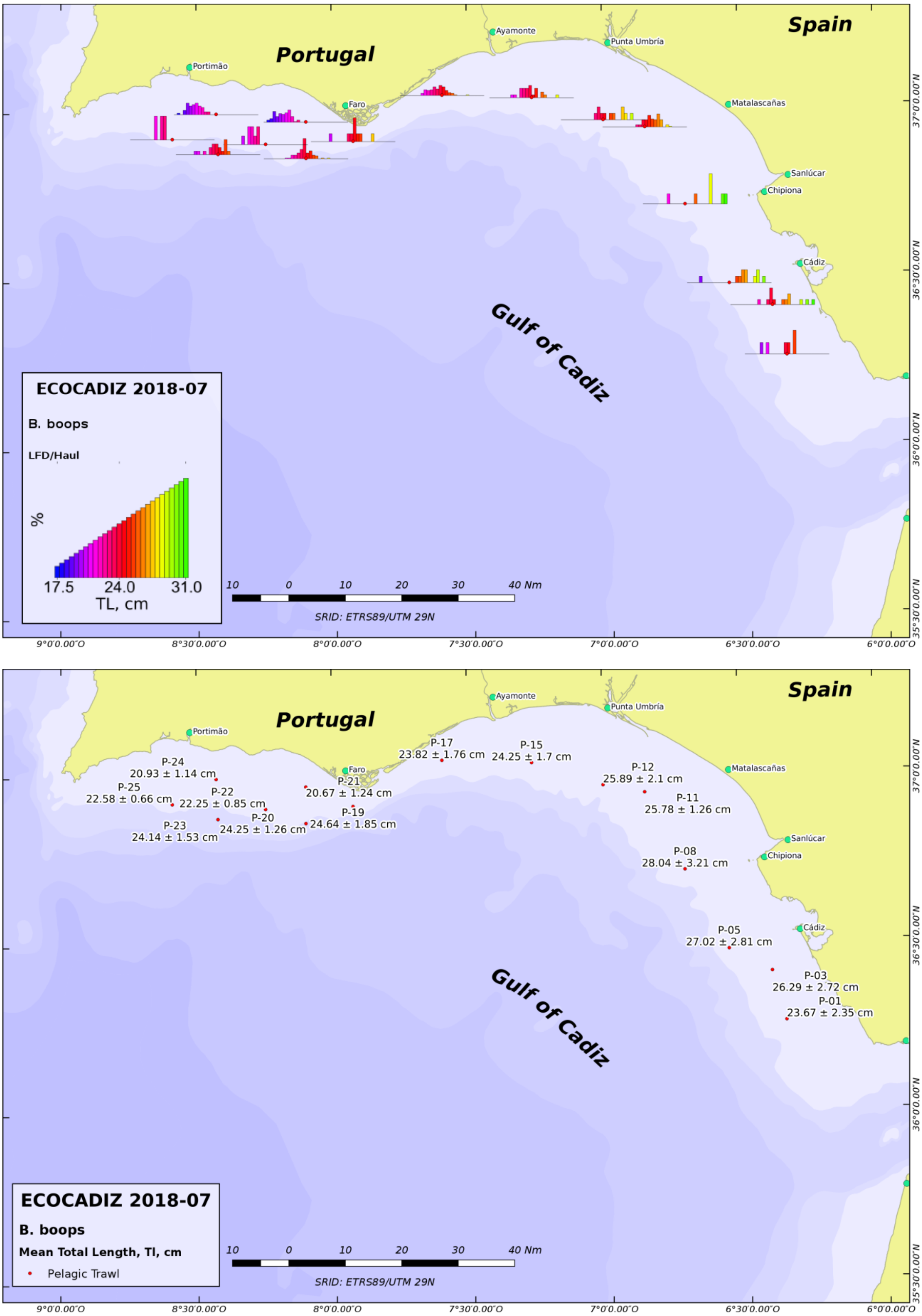



**Figure 13.** *ECOCADIZ 2018-07* survey. *Boops boops*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

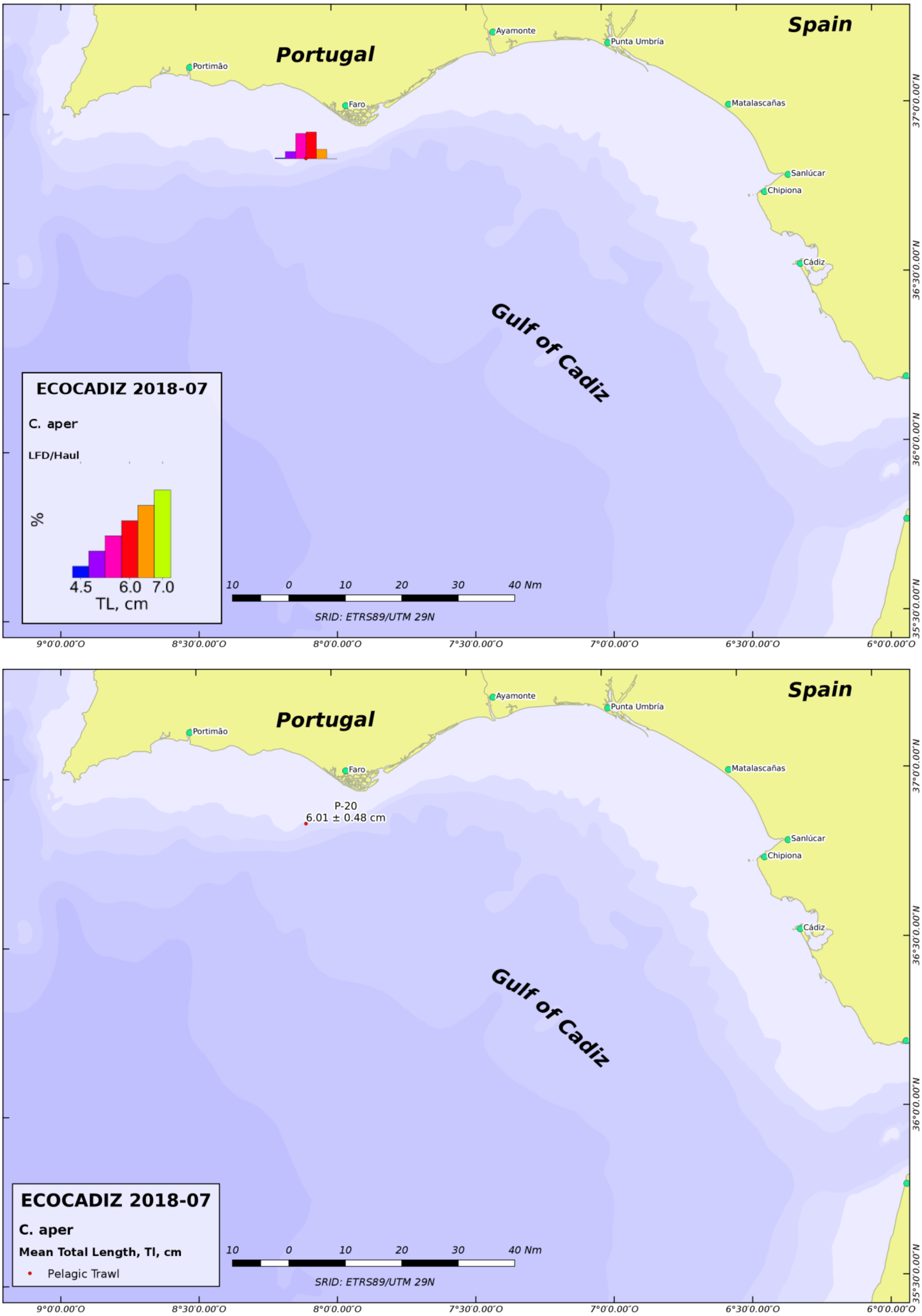



**Figure 14.** *ECOCADIZ 2017-07* survey. *Capros aper*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

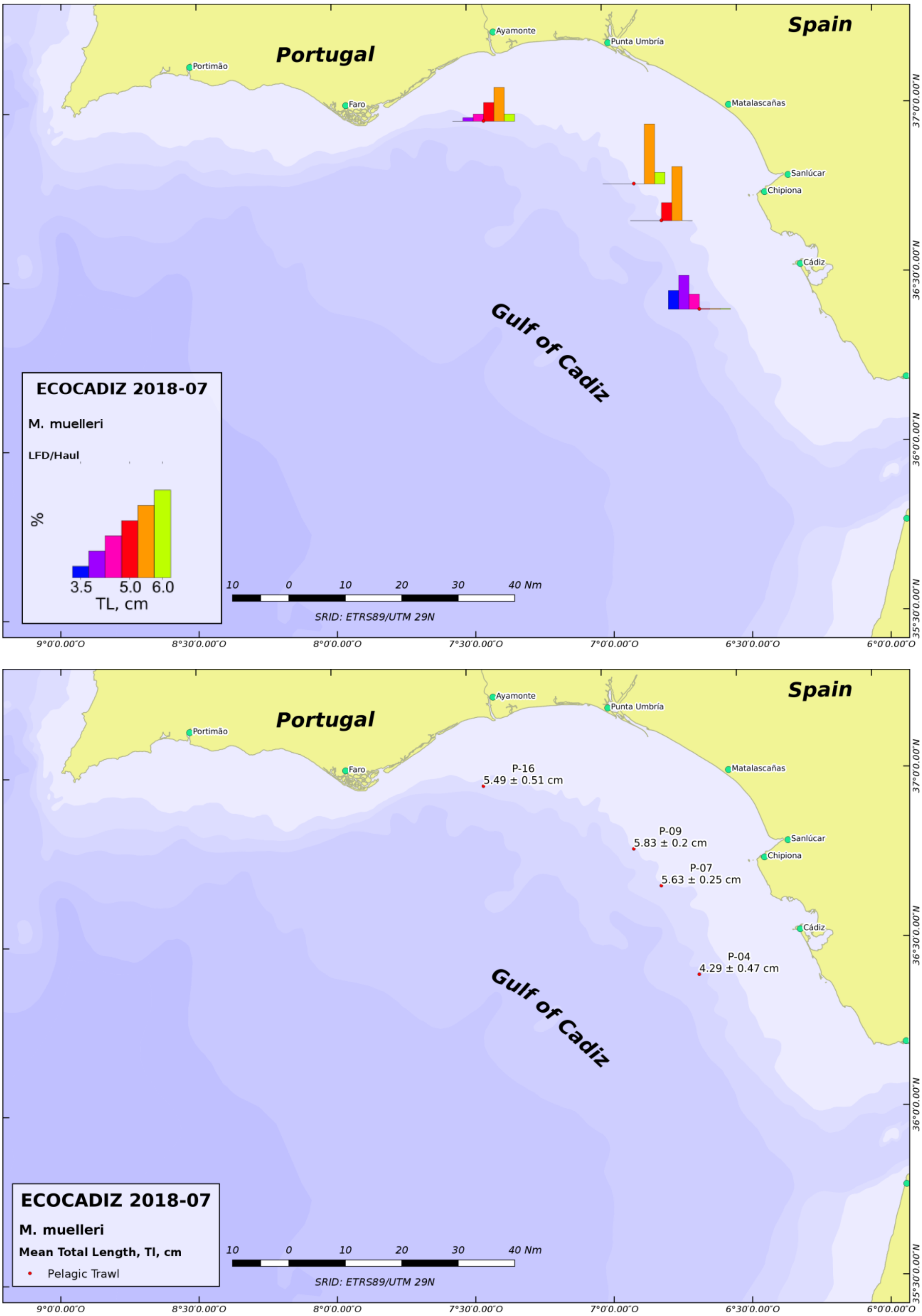
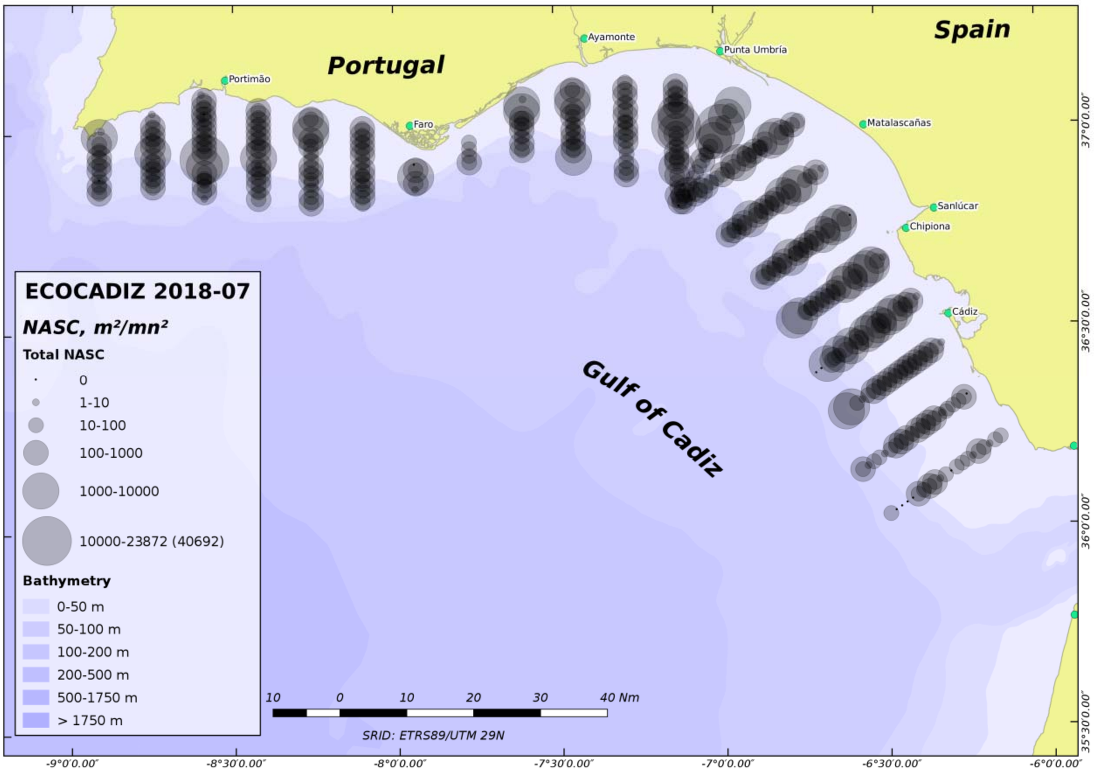



**Figure 15.** *ECOCADIZ 2017-07* survey. *Maurolicus muelleri*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.



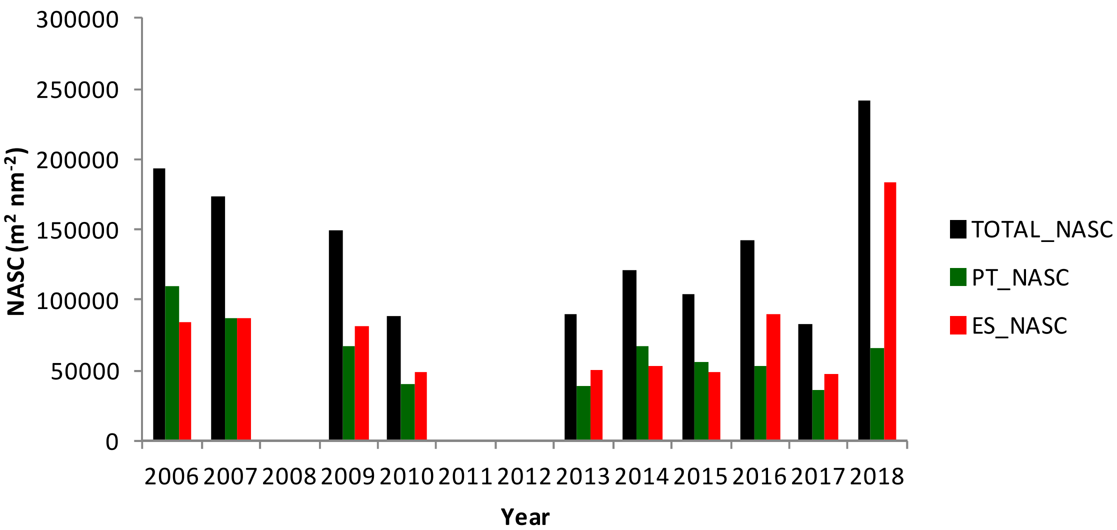




**Figure 16.** *ECOCADIZ 2018-07* survey. Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in $m^2$ $nmi^{-2}$) attributed to the pelagic fish species assemblage. Bottom: time-series of total NASC estimates per survey.

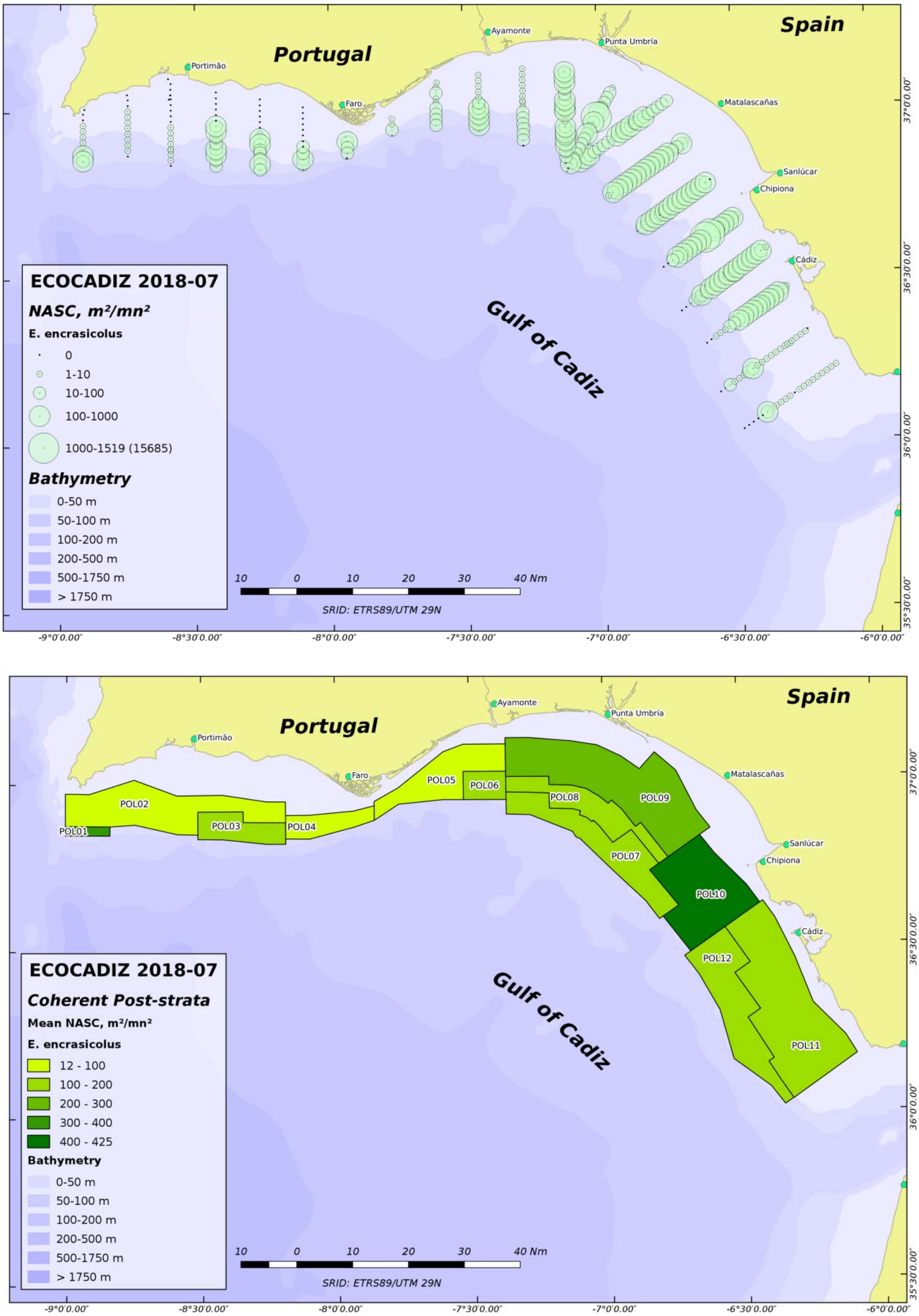



**Figure 17.** *ECOCADIZ 2018-07* survey. Anchovy (*Engraulis encrasicolus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in $m^2$ $nmi^{-2}$) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

***ECOCADIZ 2018-07*: Anchovy (*E. encrasicolus*)**

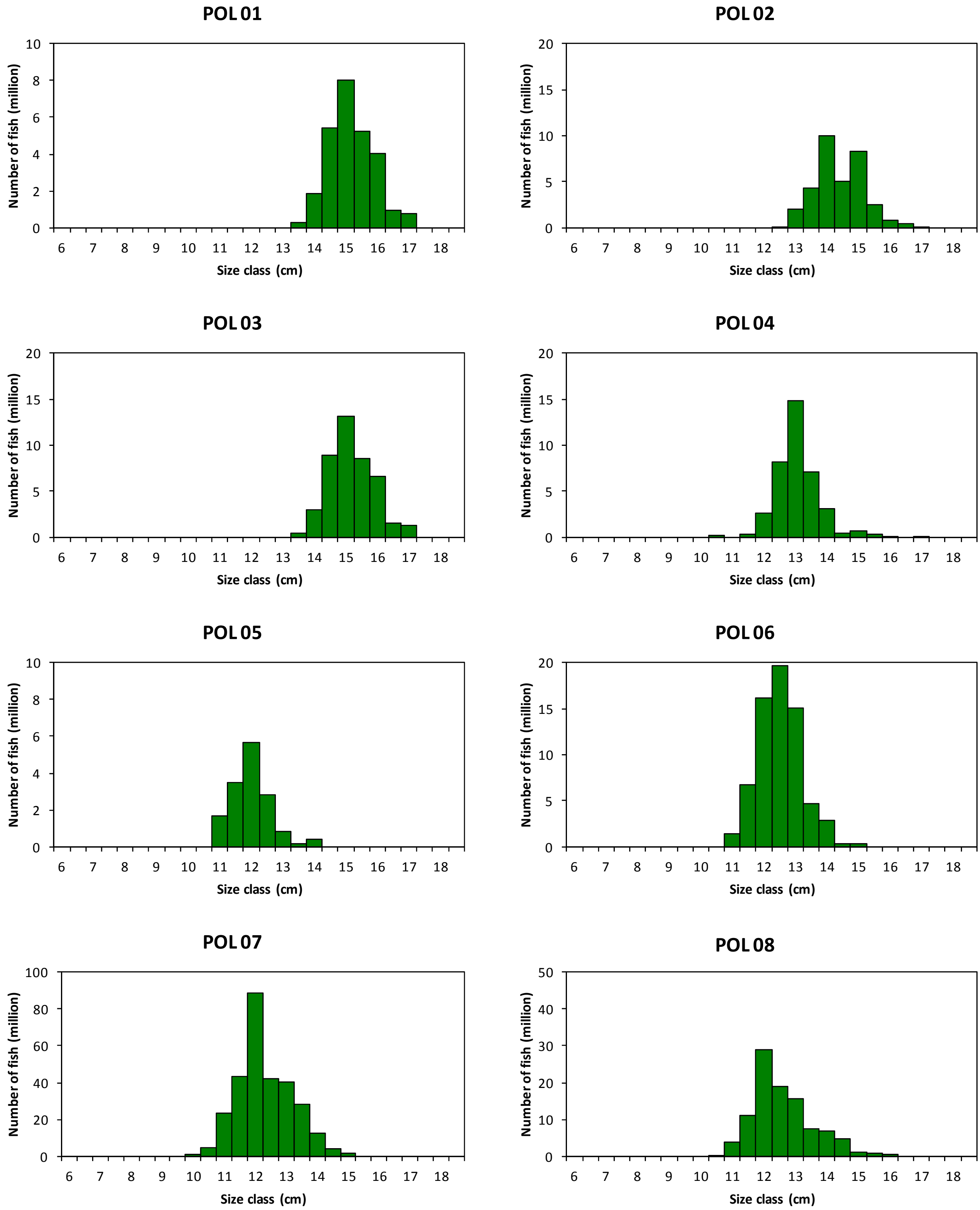



**Figure 18.** *ECOCADIZ 2018-07* survey. Anchovy (*E. encrasicolus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous stratum (POL01-POLn, numeration as in **Figure 17**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

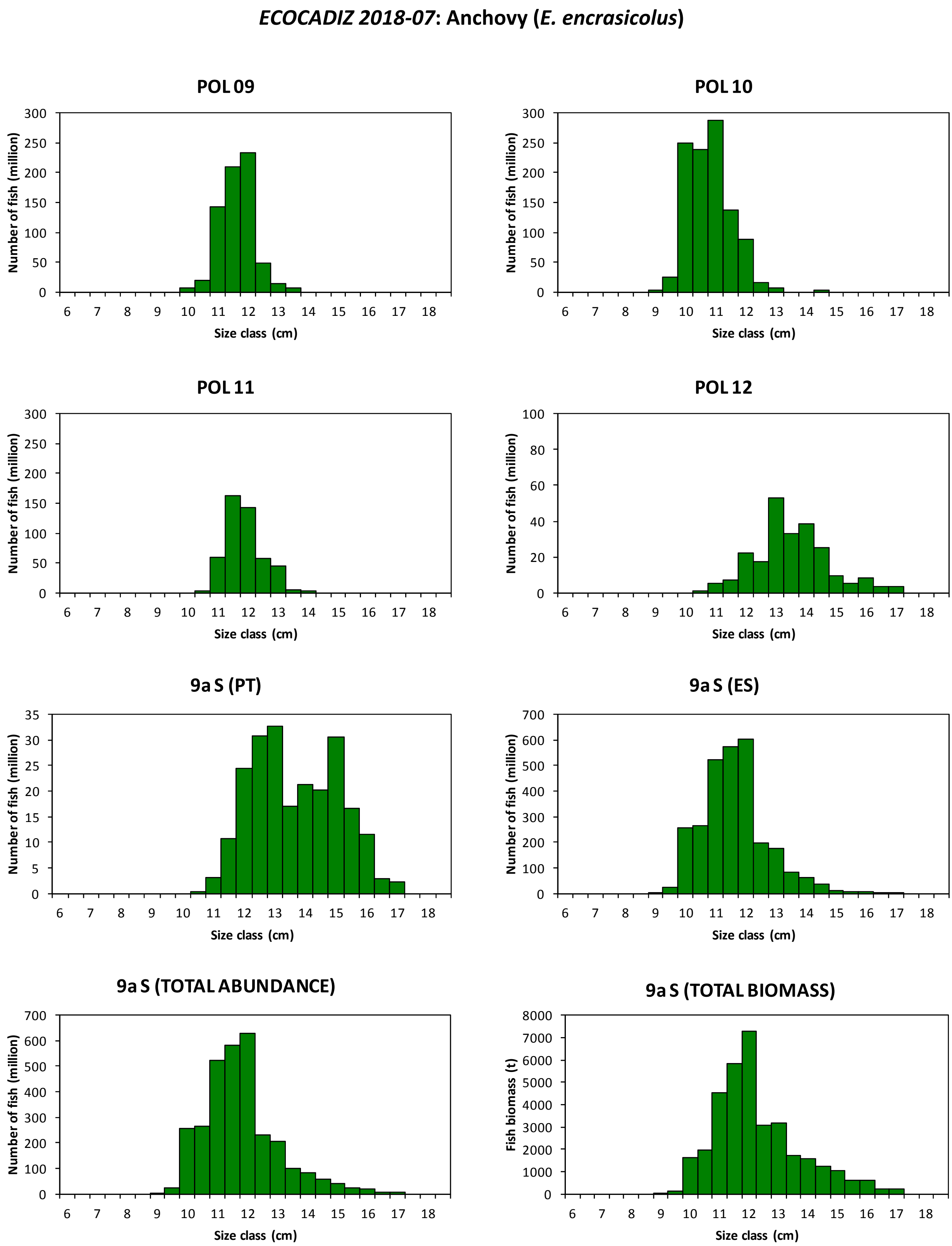



**Figure 18.** *ECOCADIZ 2018-07* survey. Anchovy (*E. encrasicolus*). Cont'd.

***ECOCADIZ 2018-07*: Anchovy (*E. encrasicolus*)**

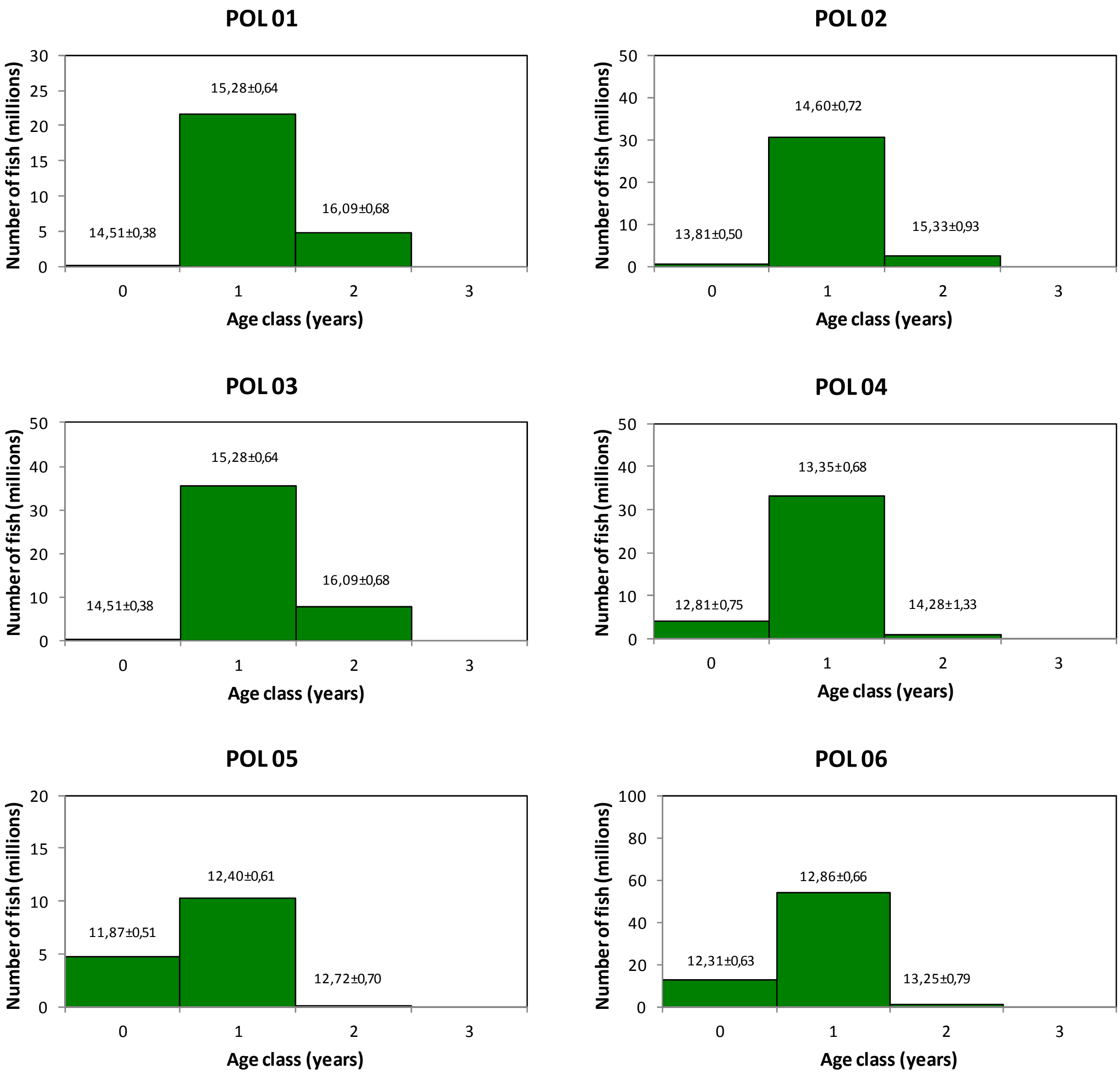



**Figure 19.** *ECOCADIZ 2018-07* survey. Anchovy (*E. encrasicolus*). Estimated abundances (number of fish in millions) by age group (years) by homogeneous stratum (POL01-POLn, numeration as in **Figure 17**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by age group for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

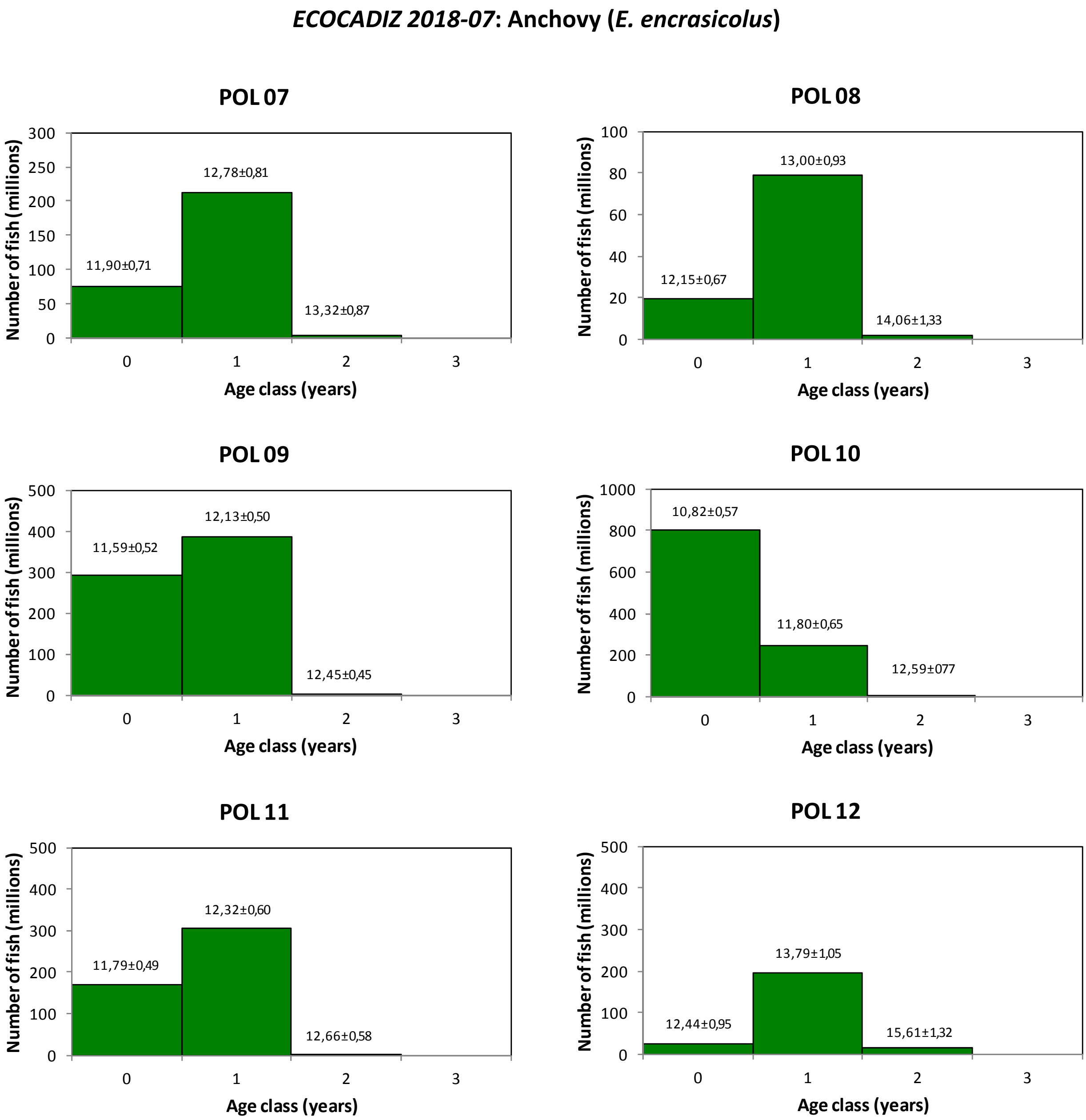



**Figure 19.** *ECOCADIZ 2018-07* survey. Anchovy (*E. encrasicolus*). Cont'd.

***ECOCADIZ 2018-07*: Anchovy (*E. encrasicolus*)**

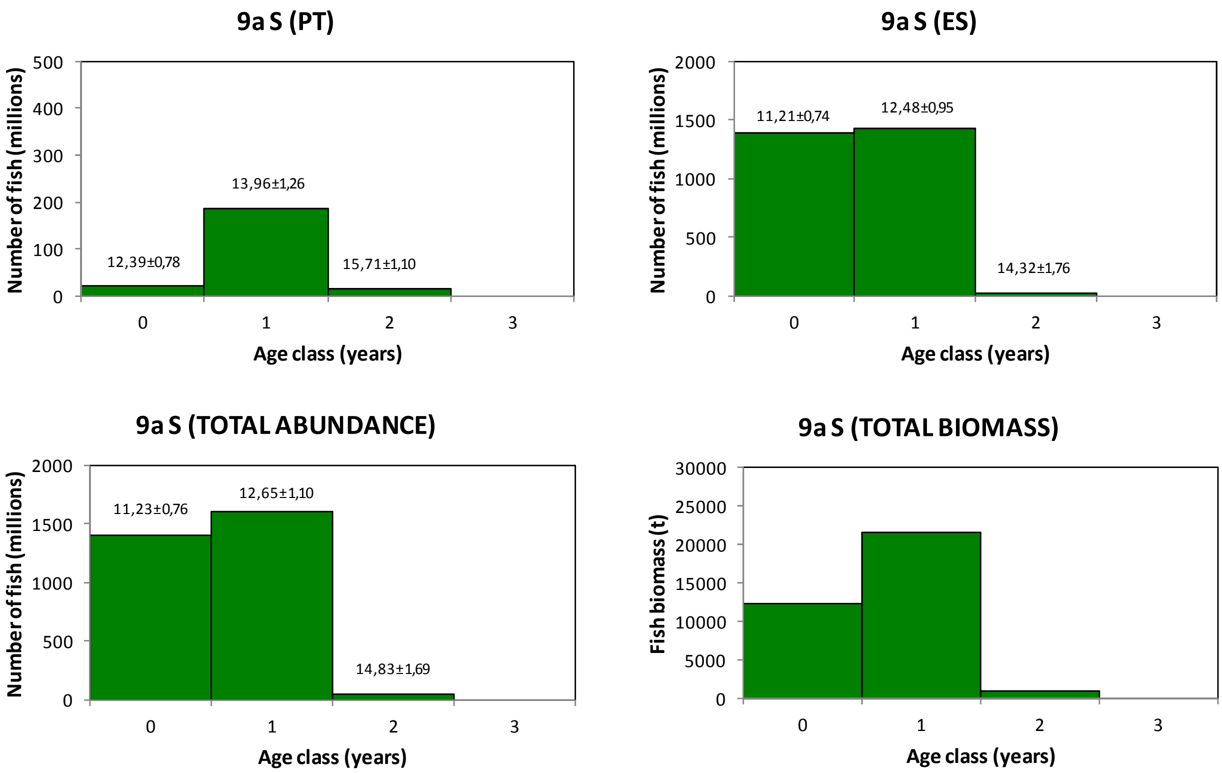
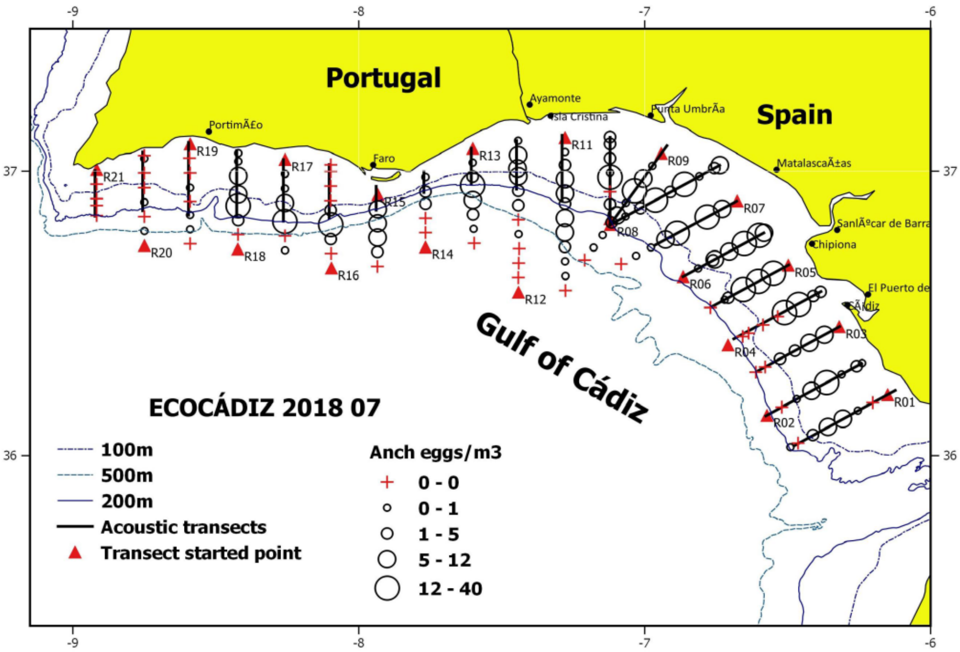
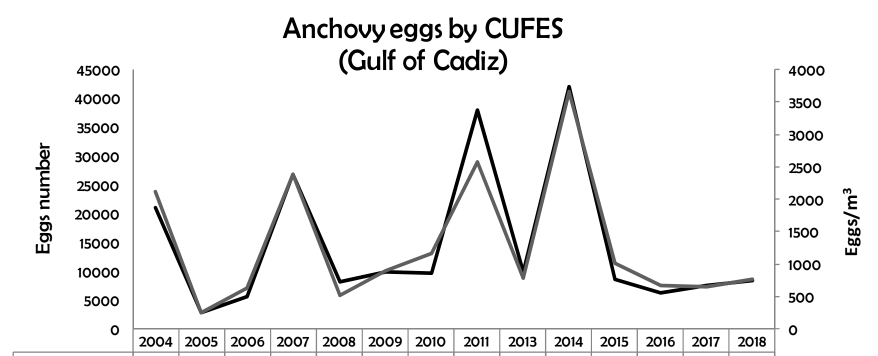



**Figure 19.** *ECOCADIZ 2018-07* survey. Anchovy (*E. encrasicolus*). Cont'd.

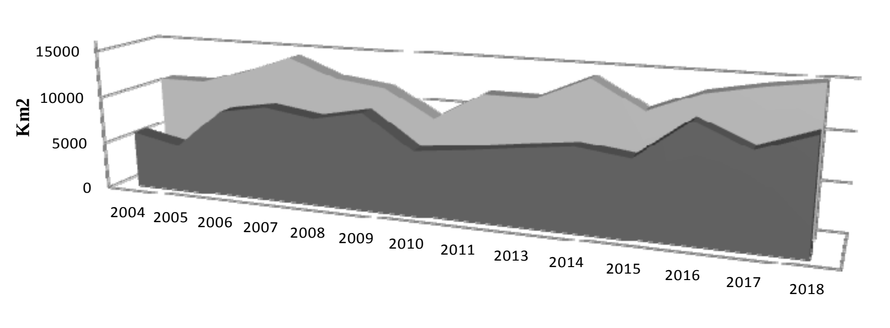



| ECOCADIZ 2018-07 | |
|---|---|
| CUFES st | 151 |
| Positive anchovy st8 | 111 (73.5 %) |
| Max number eggs by st | 1453 |
| Total anchovy eggs (in number) | 7630 |
| Max density by st (eggs/100 m$^3$) | 122 |
| Total density (eggs/100 m$^3$) | 656 |

**Figure 20.** *ECOCADIZ 2018-07* survey. Anchovy (*E. encrasicolus*). Top: distribution of anchovy egg densities sampled by CUFES (eggs m$^{-3}$). Bottom: main descriptors of the CUFES sampling. Bottom: historical series of GoC anchovy egg densities as sampled by CUFES.

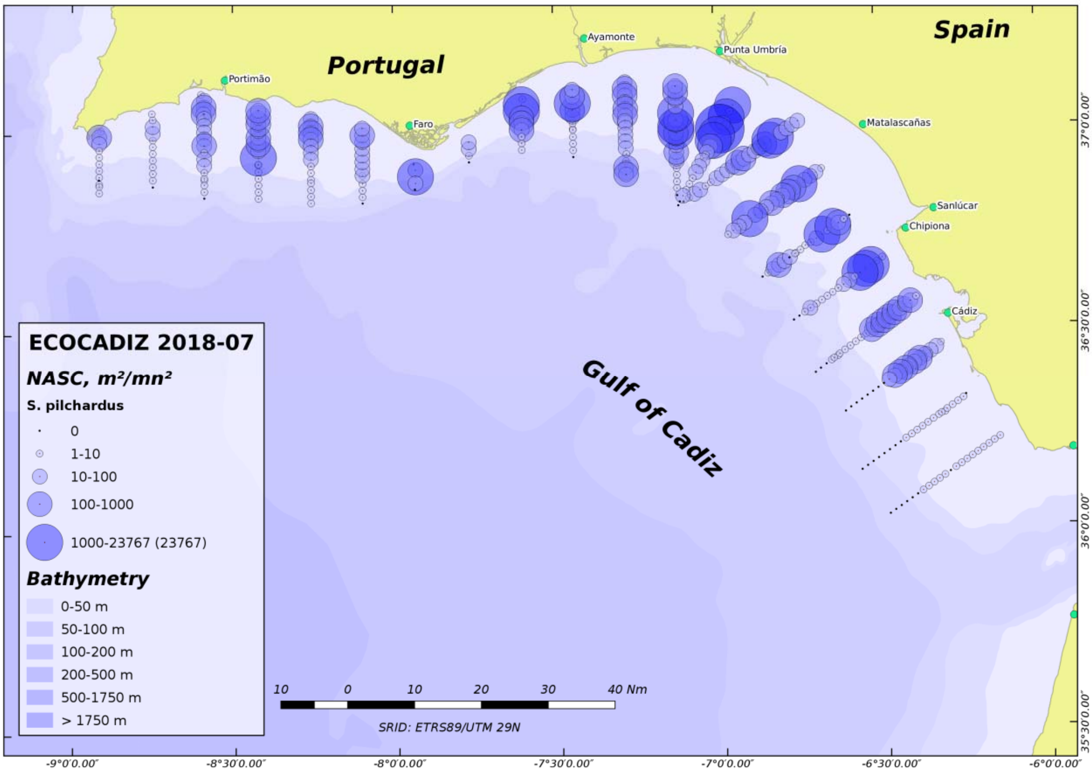



| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tot number | 21109 | 2955 | 5723 | 26770 | 8219 | 9885 | 9615 | 37831 | 10005 | 41941 | 8606 | 6298 | 7630 | 8331 |
| Tot density | 2108 | 257 | 641 | 2374 | 530 | 901 | 1176 | 2565 | 786 | 3657 | 1010 | 672 | 656 | 766 |




| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spawning area | 5934 | 4962 | 9064 | 9879 | 9172 | 10152 | 6678 | 7251 | 7922 | 8535 | 7906 | 11855 | 9634 | 11498 |
| Surveyed area | 10846 | 10891 | 12394 | 14150 | 12246 | 11635 | 8837 | 11776 | 11774 | 14045 | 11243 | 13348 | 14335 | 15078 |

**Figure 20.** *ECOCADIZ 2018-07* survey. Anchovy (*E. encrasicolus*). Cont'd. Top: historical series of GoC anchovy egg total numbers and densities (eggs * $m^{-3}$) sampled by CUFES. Bottom: historical series of estimates of the extension of the GoC anchovy spawning area (in $km^2$).



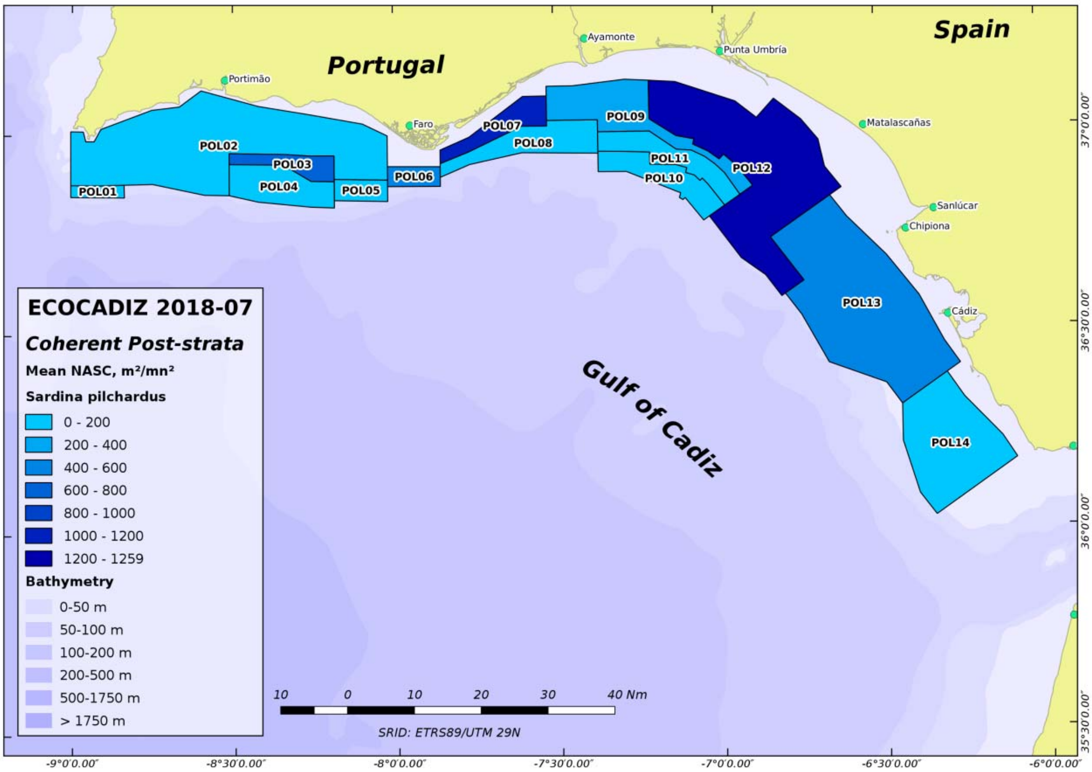




**Figure 21.** *ECOCADIZ 2018-07* survey. Sardine (*Sardina pilchardus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in $m^2$ $nmi^{-2}$) attributed to the species Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

***ECOCADIZ 2018-07*: Sardine (*S. pilchardus*)**

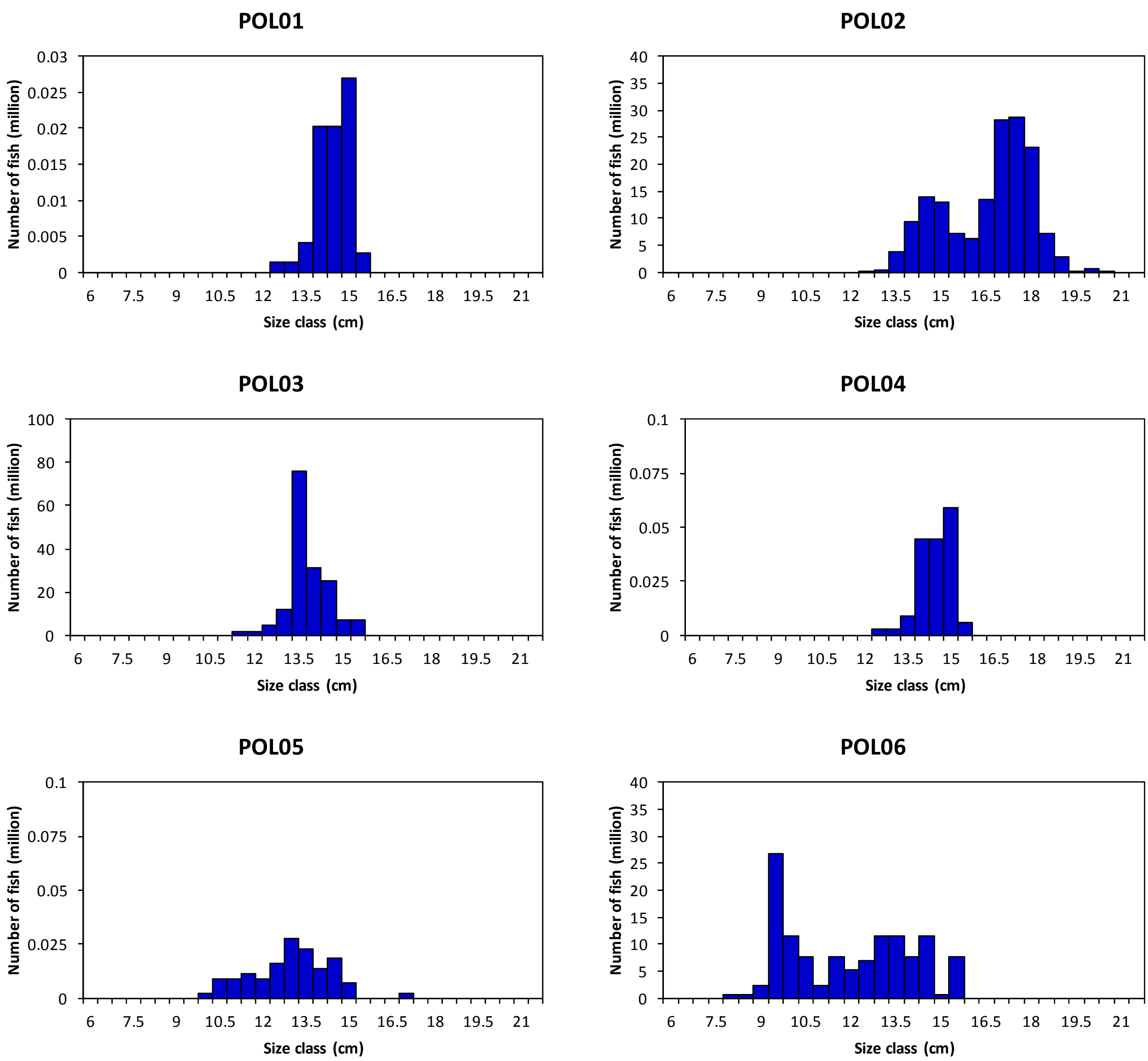



**Figure 22.** *ECOCADIZ 2018-07* survey. Sardine (*S. pilchardus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous stratum (POL01-POLn, numeration as in **Figure 21**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

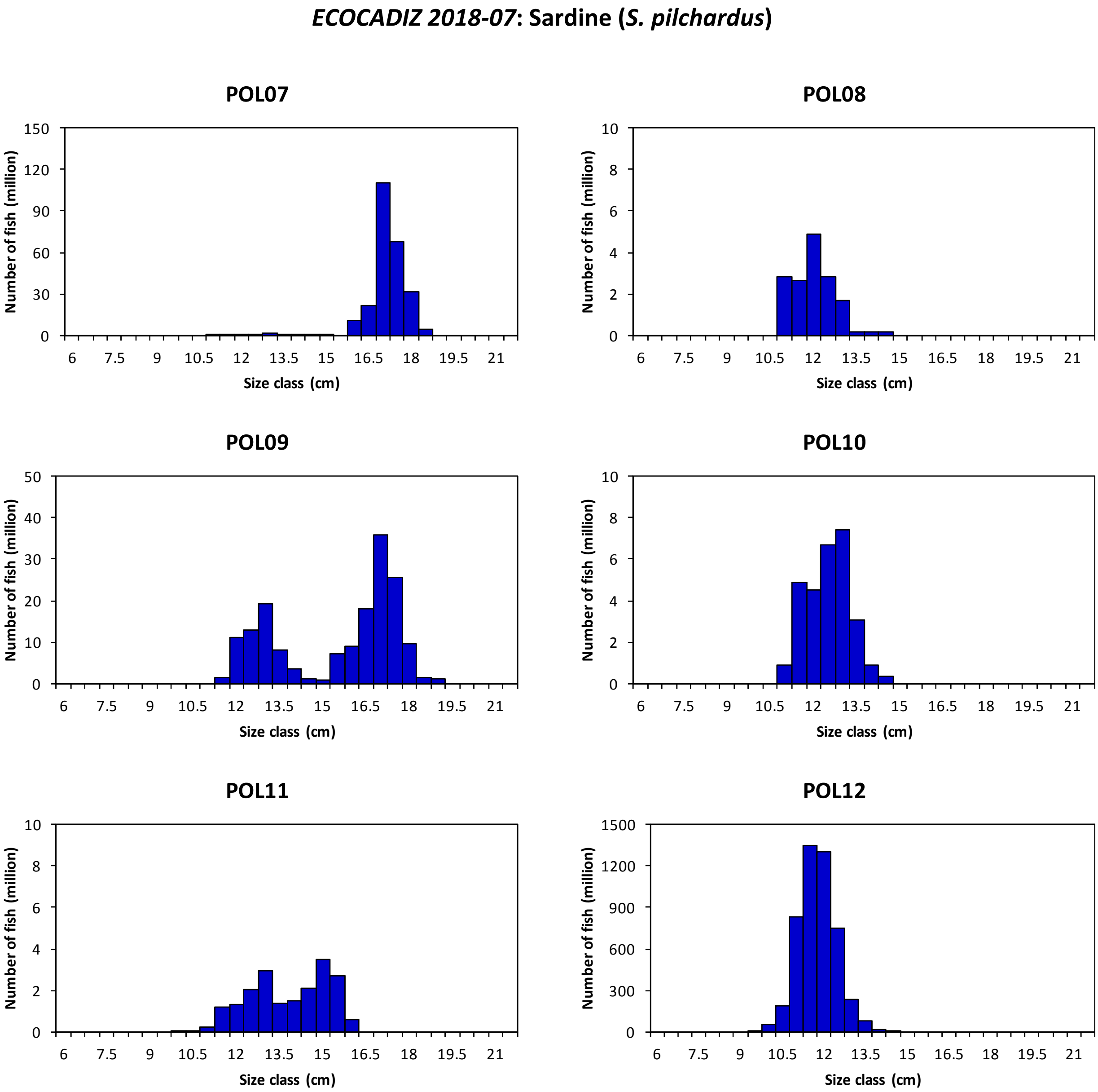



**Figure 22.** *ECOCADIZ 2018-07* survey. Sardine (*S. pilchardus*). Cont'd.

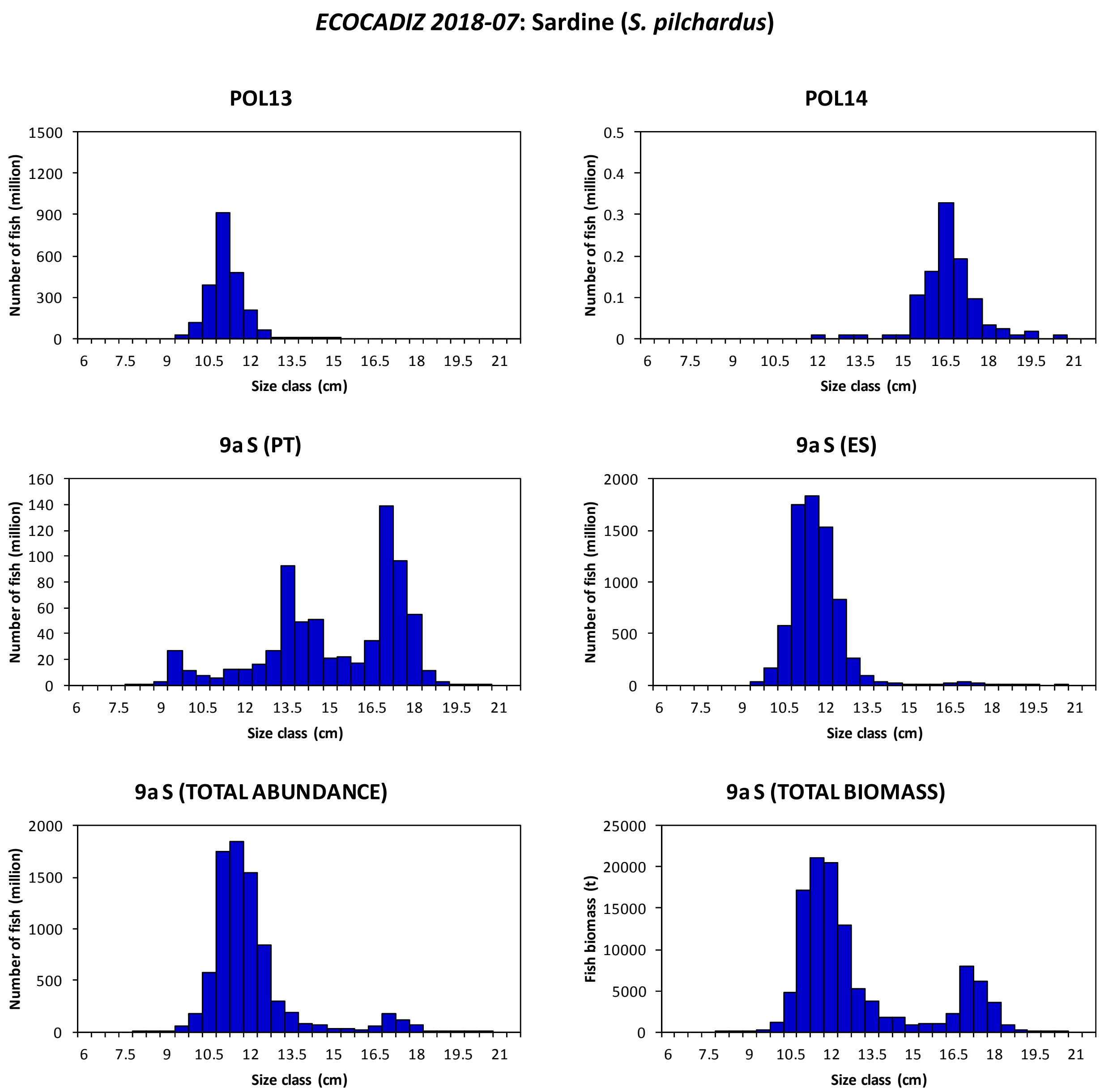



**Figure 22.** *ECOCADIZ 2018-07* survey. Sardine (*S. pilchardus*). Cont'd.

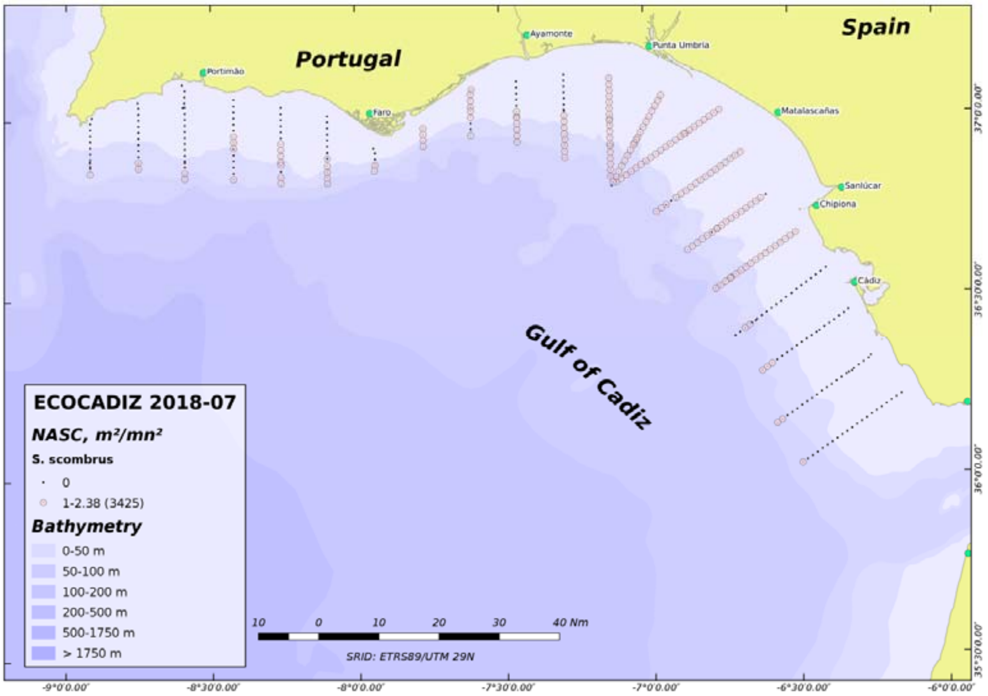



**Figure 23.** *ECOCADIZ 2018-07* survey. Mackerel (*Scomber scombrus*). Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in $m^2$ $nmi^{-2}$) attributed to the species.

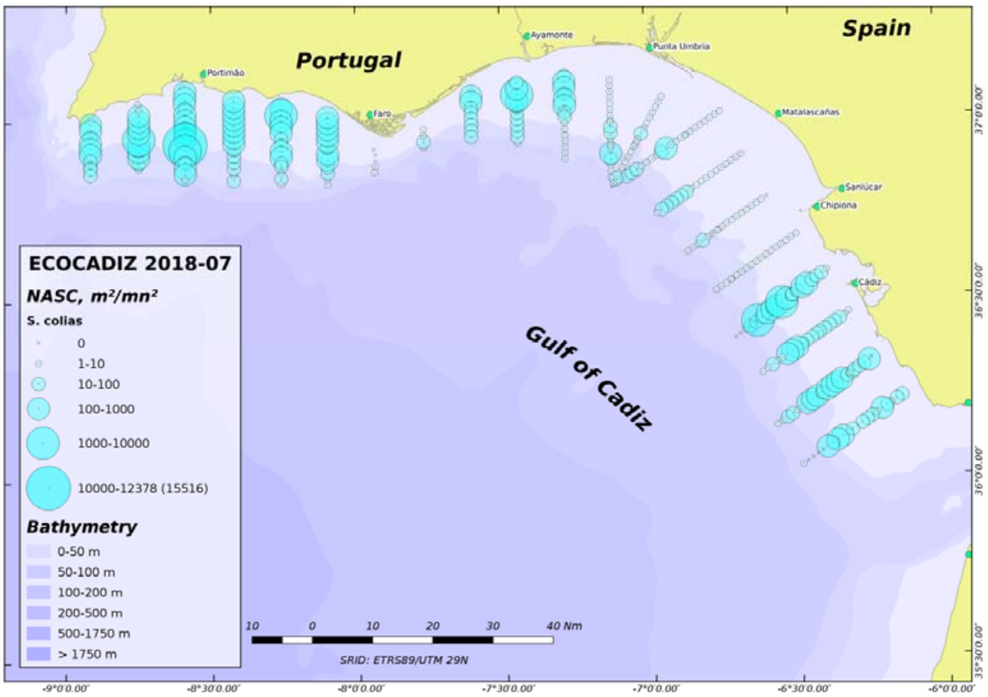



**Figure 24.** *ECOCADIZ 2018-07* survey. Chub mackerel (*Scomber colias*). Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in $m^2$ $nmi^{-2}$) attributed to the species.

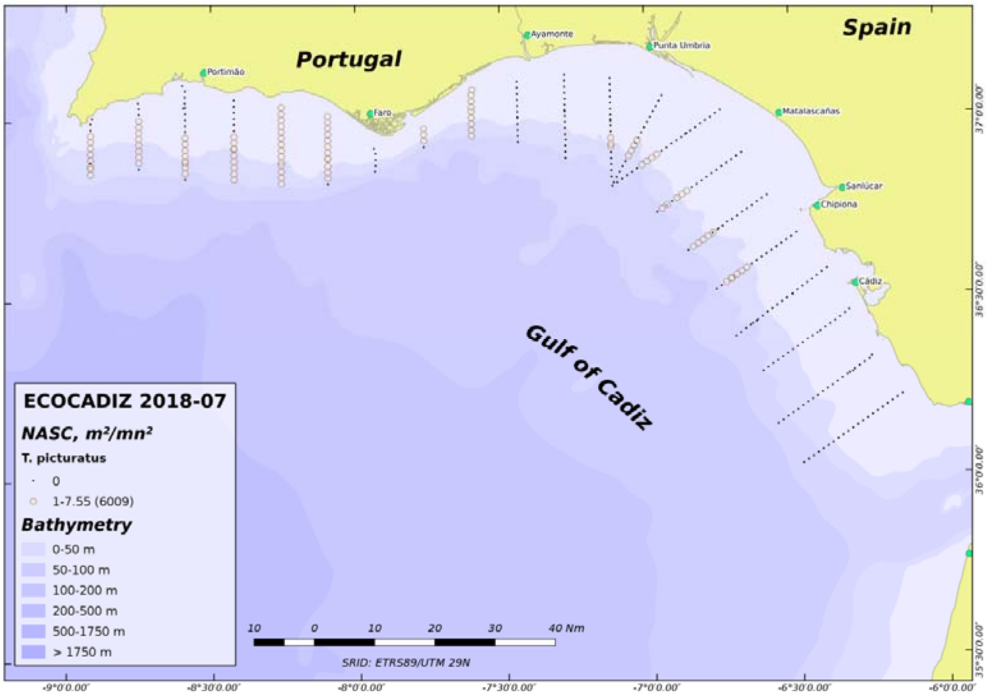



**Figure 25.** *ECOCADIZ 2018-07* survey. Blue jack mackerel (*Trachurus picturatus*). Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in $m^2$ $nmi^{-2}$) attributed to the species.

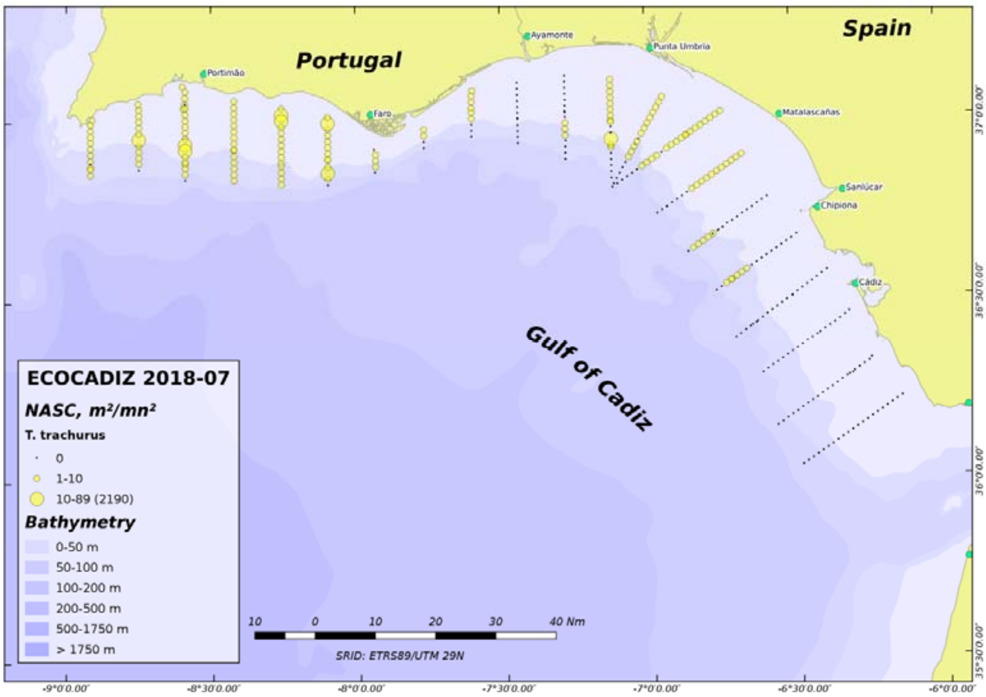



**Figure 26.** *ECOCADIZ 2018-07* survey. Horse mackerel (*Trachurus trachurus*). Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in $m^2$ $nmi^{-2}$) attributed to the species.

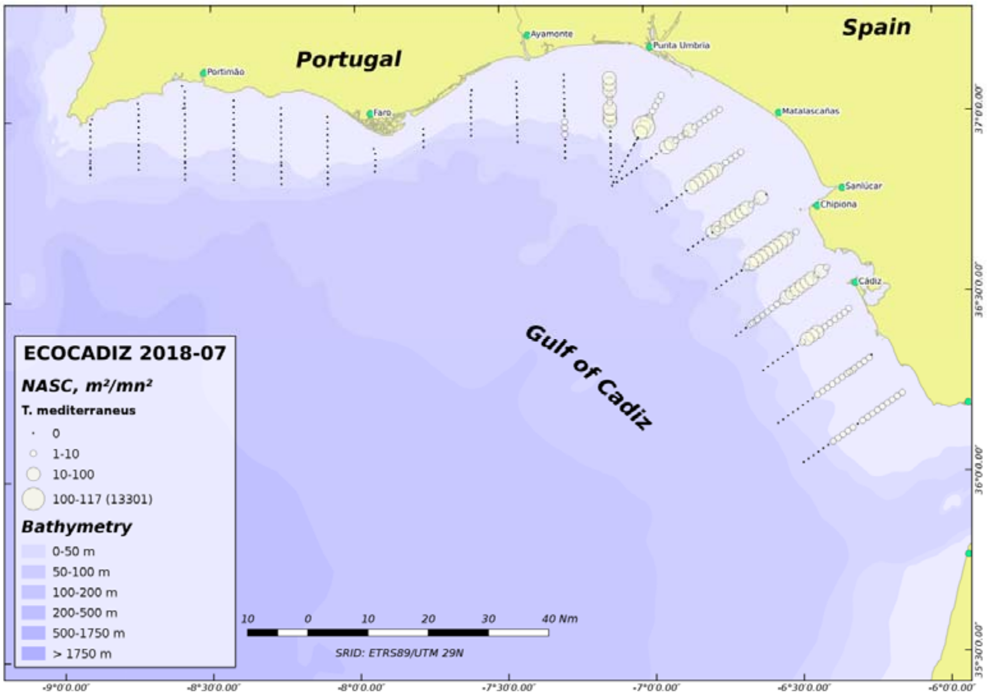



**Figure 27.** *ECOCADIZ 2018-07* survey. Mediterranean horse mackerel (*Trachurus mediterraneus*). Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m$^2$ nmi$^{-2}$) attributed to the species.

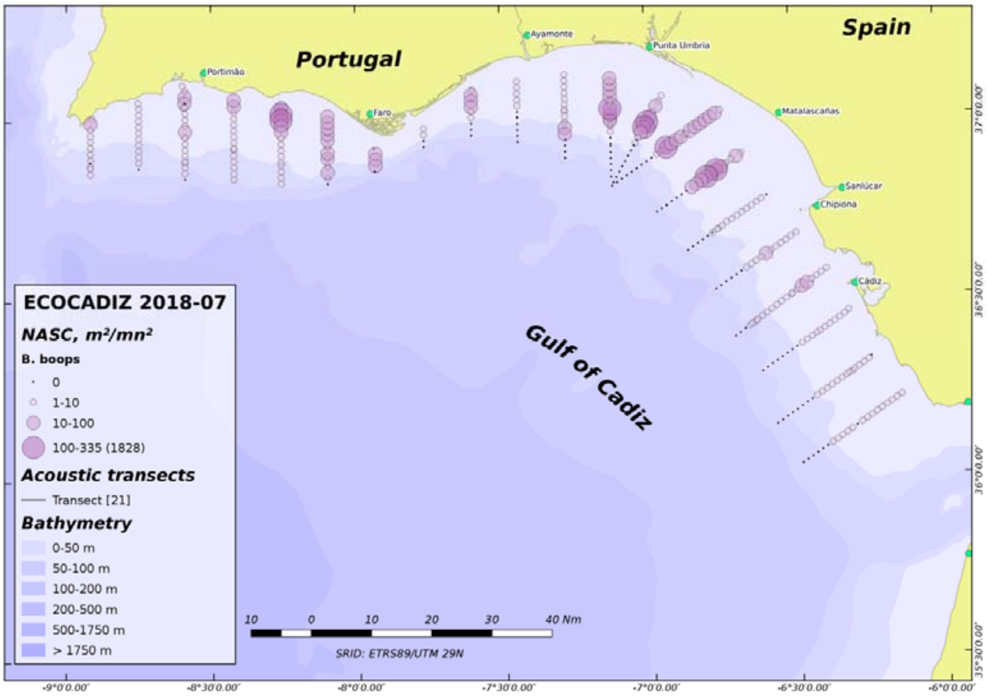



**Figure 28.** *ECOCADIZ 2018-07* survey. Bogue (*Boops boops*). Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m$^2$ nmi$^{-2}$) attributed to the species.

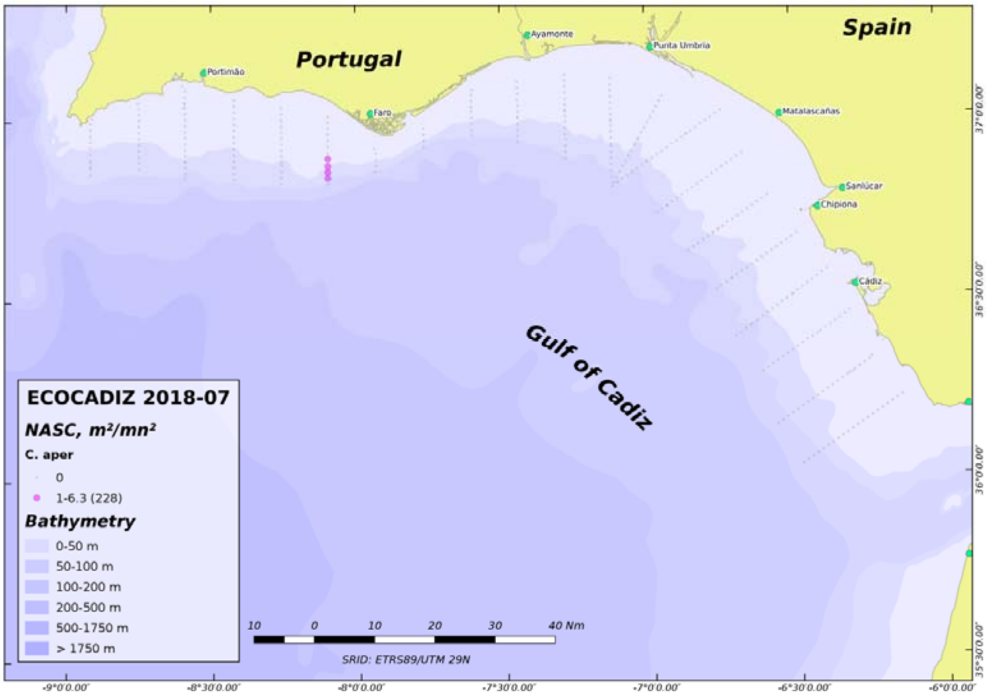



**Figure 29.** *ECOCADIZ 2018-07* survey. Boarfish (*Capros aper*). Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in $m^2$ $nmi^{-2}$) attributed to the species.

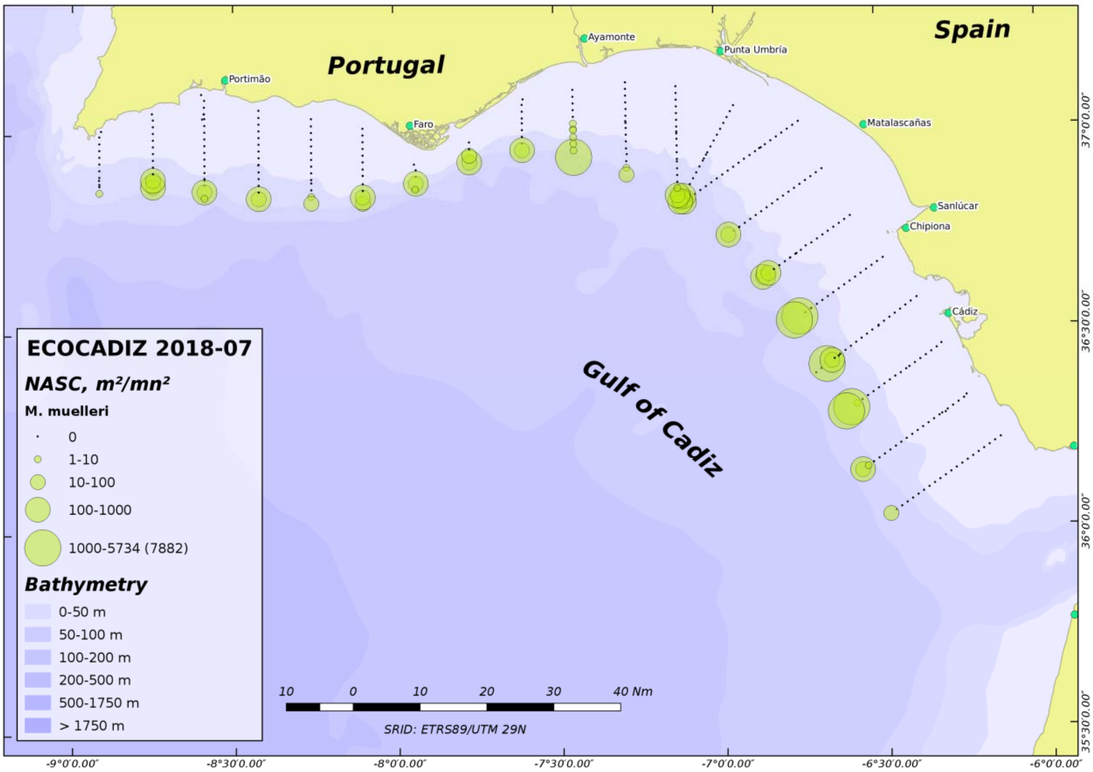
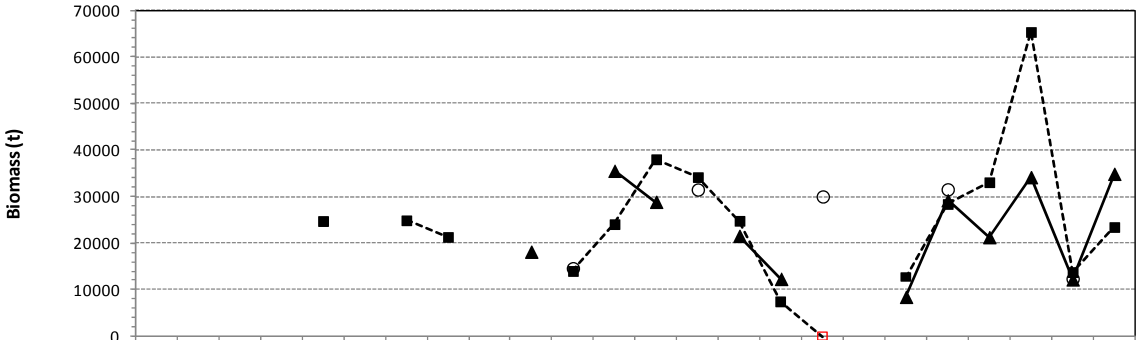



**Figure 30.** *ECOCADIZ 2018-07* survey. Silvery lightfish (*Maurolicus muelleri*). Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in $m^2$ $nmi^{-2}$) attributed to the species.

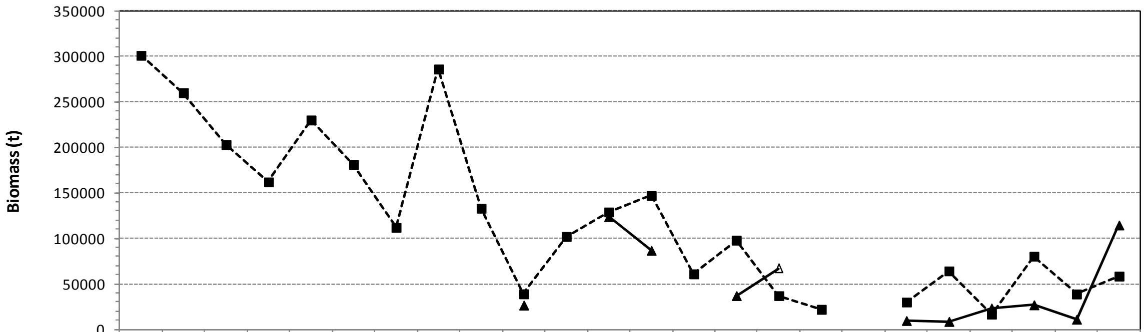
## Biomass trends (in tons)

### Anchovy biomass estimates




| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PELAGO | | | | | 24763 | | 24913 | 21335 | | | 14041 | 24082 | 38020 | 34200 | 24800 | 7395 | 0 | | 12700 | 28408 | 33100 | 65345 | 13797 | 23473 |
| ECOCADIZ | | | | | | | | | | 18177 | | 35539 | 28882 | | 21580 | 12339 | | | 8487 | 29219 | 21305 | 34184 | 12229 | 34908 |
| BOCADEVA | | | | | | | | | | | 14637 | | | 31527 | | | 30037 | | | 31569 | | | 12392 | |

### Sardine biomass estimates




| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PELAGO | 301000 | 260000 | 203000 | 162000 | 230000 | 181000 | 112000 | 286000 | 133000 | 39000 | 102000 | 129000 | 147000 | 61000 | 98000 | 37000 | 22000 | | 30000 | 64227 | 16663 | 80356 | 38873 | 58561 |
| ECOCADIZ | | | | | | | | | | 26568 | | 123849 | 86777 | | 37020 | 66964 | | | 9670 | 8697 | 23460 | 26919 | 11053 | 114631 |

**Figure 31.** Trends in biomass estimates (in tons) for the main assessed species in Portuguese (*PELAGO*) and Spanish (*ECOCADIZ* and *BOCADEVA*) survey series. Note that the *ECOCADIZ* survey in 2010 partially covered the whole study area. The anchovy null estimate in 2011 from the *PELAGO* survey should be considered with caution.

**ANNEX**

(Figures of echograms showing dense sardine schools in shallow waters. EK60 echo-sounder. 38 kHz).

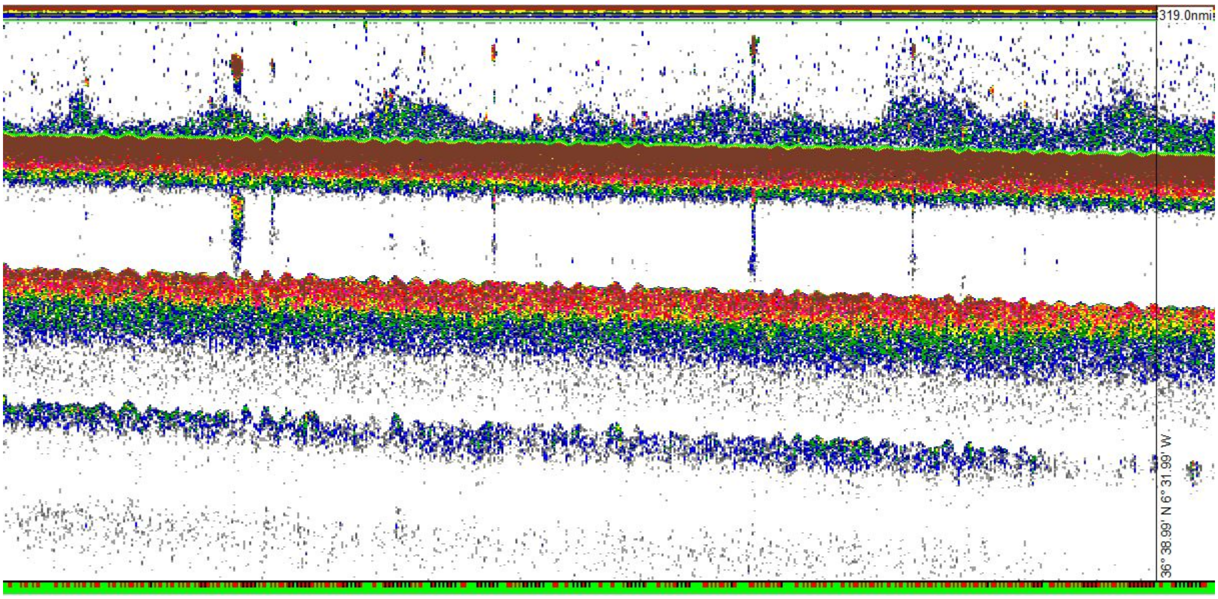



**Figure A1**. Transect RA05 (Chipiona), 23-25 m depth.

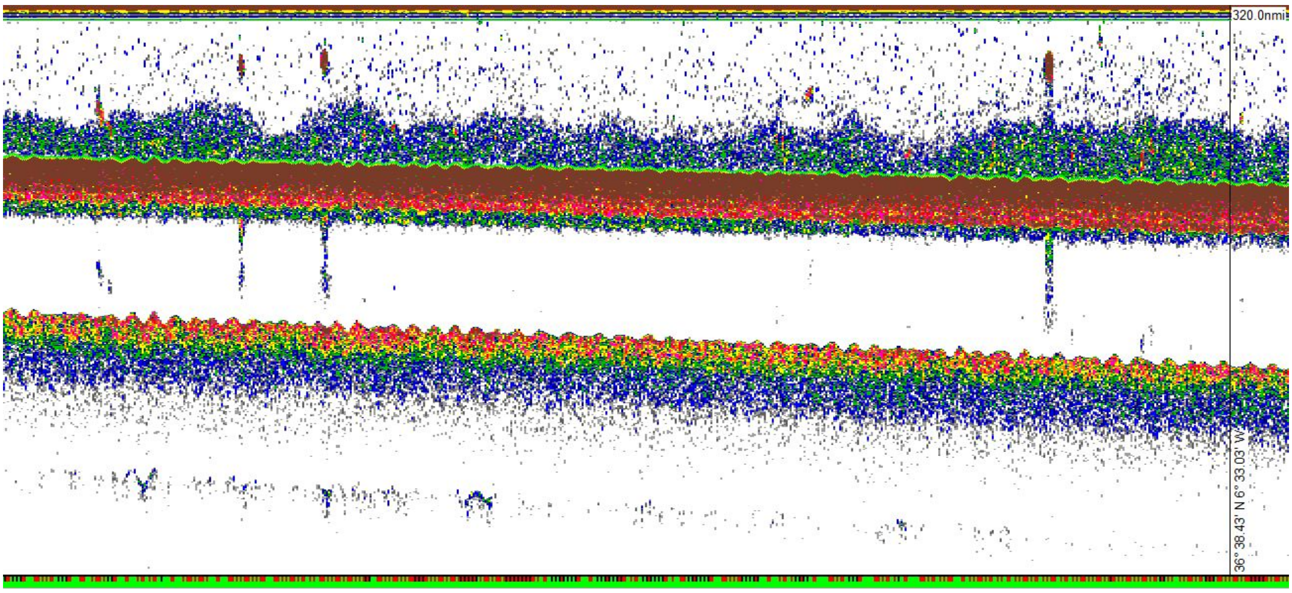



**Figure A2**. Transect RA05 (Chipiona), 27-29 m depth.

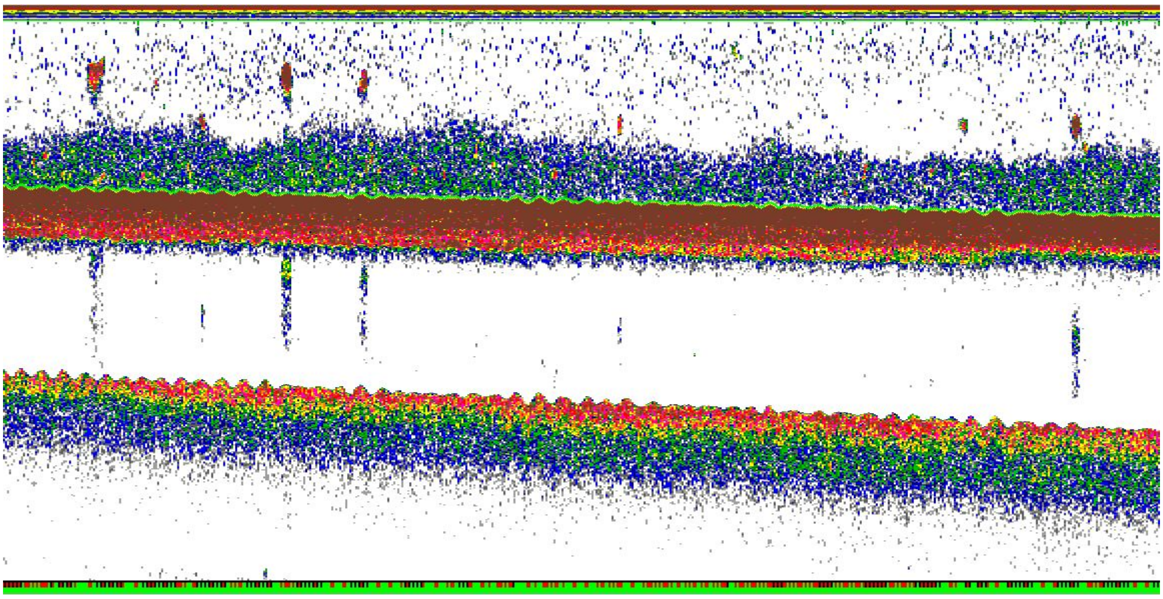


**Figure A3**. Transect RA05 (Chipiona), 31-37 m depth.

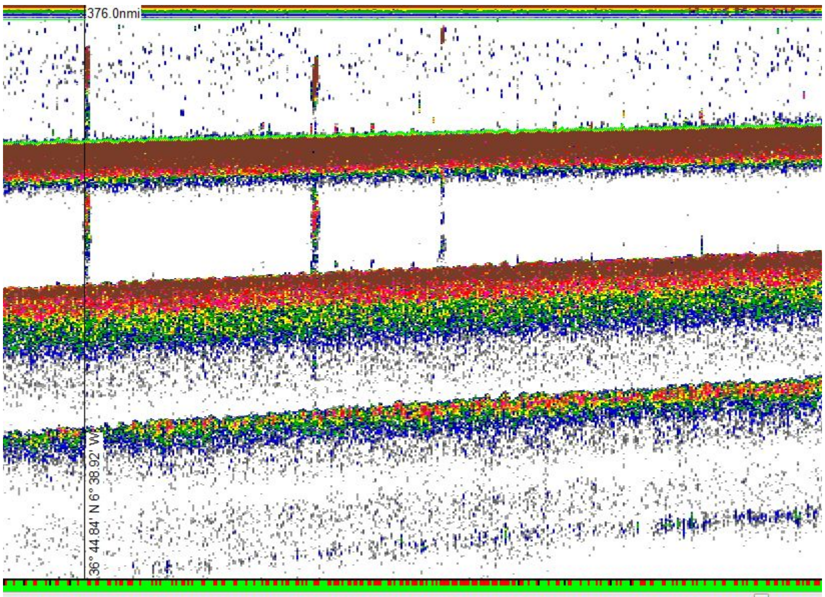



**Figure A4**. Transect RA06 (Doñana), 23-24 m depth.

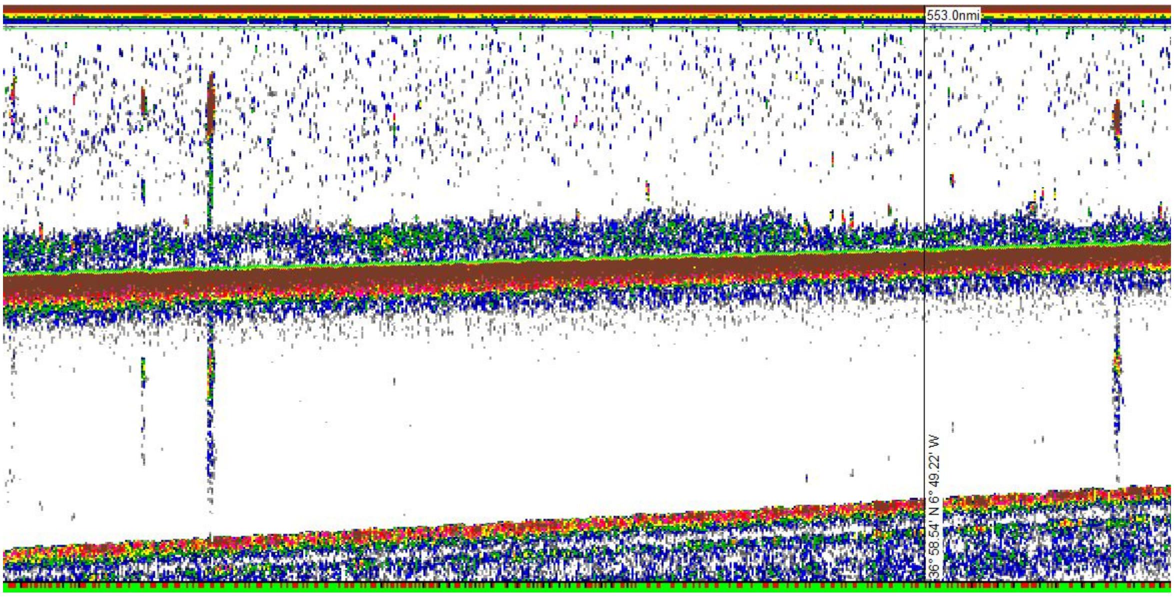



**Figure A5**. Transect RA08 (Mazagón), 23-24 m depth.

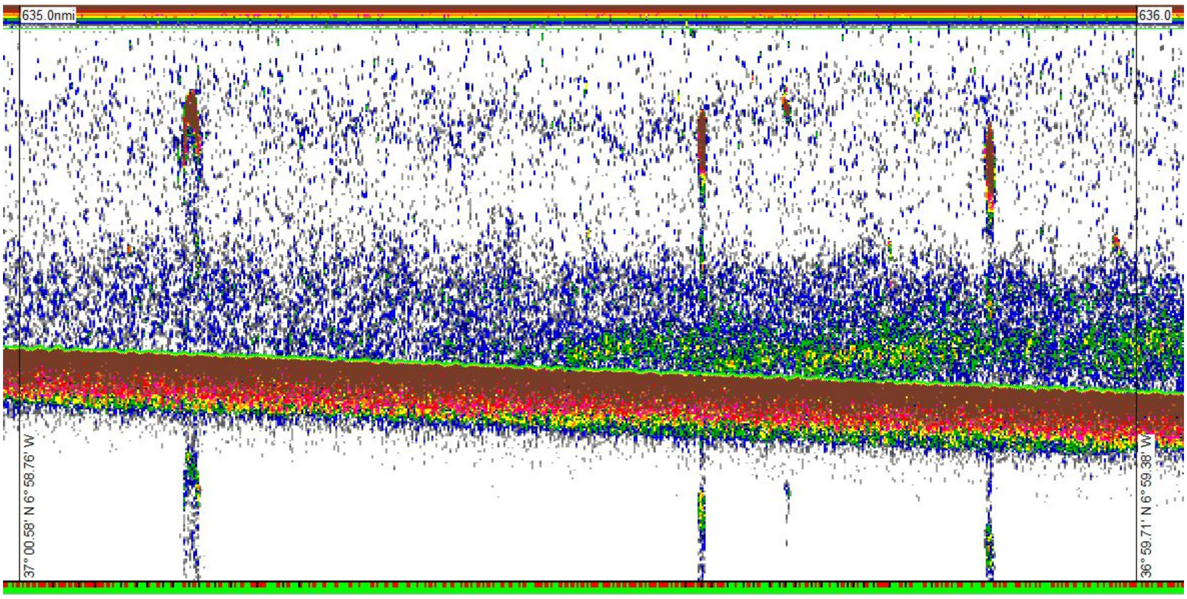



**Figure A6**. Transect RA10 (El Rompido), 40-44 m depth.

## Annex 3.6: Western European Shelf Pelagic Acoustic Survey (WESPAS) 2018

*Please see report on next page.*

# FSS Survey Series: 2018/03

# Western European Shelf Pelagic Acoustic Survey (WESPAS)

10 June – 24 July, 2018

Ciaran O'Donnell[1], Michael O'Malley[1], Deirdre Lynch[1], Eugene Mullins[1], Niall Keogh[2*], John Power[3*], Aidan Long[4*], Peter Croot[4*]

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# 1 Introduction

The WESPAS survey program is the consolidation of two existing survey programs carried out by FEAS, the Malin Shelf herring acoustic survey and the boarfish acoustic survey. The Malin Shelf herring acoustic survey has been carried out annually since 2008 and reports on the annual abundance of summer feeding aggregations of herring to the west of Scotland and to the north and west of Ireland from 54°N to 58°30'N. The boarfish survey was conducted from 2011 using a chartered fishing vessel and reported the abundance of spawning aggregations of boarfish from 47°N to 57°N. In 2016 both surveys were combined and since then have been carried out onboard the RV *Celtic Explorer* over a 42 day period providing synoptic coverage of shelf waters from 47°N northwards to 58°30'N.

Age stratified relative stock abundance estimates of boarfish, herring and horse mackerel within the survey area were calculated using acoustic data and biological data from trawl sampling. Stock estimates of boarfish and horse mackerel were submitted to the ICES assessment Working Group for Widely Distributed Stocks (WGWIDE) meeting in August 2018. Herring estimates are submitted to the Herring Assessment Working Group (HAWG) meeting in March every year. Survey performance will be reviewed at the ICES Planning Group meeting for International Pelagic Surveys (WGIPS) meeting in January 2019.

# 2 Materials and Methods

## 2.1 Scientific Personnel

| | | |
|---|---|---|
| Leg | CE18CC9 | CE18C1C |
| Dates | C9-28 June | C4-24 Ju y |
| Days | 2C | 22 |
| Start | Ga way | Ga way |
| End | Ga way | Ga way |
| Acou (Ch ef Sc ) | C aran O'Do nne | M chae O 'Ma ey |
| Acou | Tur och Sm th | Brendan O'Hea |
| Acou | De rdre Lynch | Eugene Mu ns |
| Acou | Dav d Tu y | Tob Rapp |
| B o (Deck Sc ) | Marc n B aszkowsk | an Murphy |
| B o | Seán M cLaugh n | Sean O'C onnor |
| B o | Hannah Ko egh | Artur Opanowsk |
| B o | M chae K neen | John Power |
| MMO | John Power | Cather ne O'Su van |
| SBO | John Co ns | Ash ey Johnsto n |
| SBO | Dann e e Crow ey | Sa y O'Meara |
| Zoo/Sa ps | A dan Long | A dan Long |
| Zoo/Sa ps | Le gh Barnwa | Stephan e L nehan |
| C DOM – | Cather ne Jordan | Mon ca Mu ns |
| C DOM – | Mark Dwyer | John Phe an |
| C DOM – | Kev n McGook n | - |

## 2.2 Survey Plan

### 2.2.1 Survey objectives

The primary survey objectives are listed below:

- Collect acoustic density measurements of boarfish, herring and horse mackerel within a pre-determined survey area using a split-beam echosounder (EK60) over multi frequencies
- Determine an age stratified estimate of biomass and abundance for the above target species from survey data
- Collect biological samples from directed trawling on fish echotraces to determine age structure and maturity state of target stocks
- Take morphometric and genetic samples of individual herring in 6a/7b,c for stock identification analysis
- Use vertical CTD casts to determine hydrographic conditions and the extent of shelf frontal regions

- Collect plankton samples using dedicated vertical trawls to determine biomass of zooplankton and the spatial extent of areas of concentration
- Carry out visual surveys to determine the abundance and distribution of marine mammals and seabirds (ESAS) and surface litter.
- Use multi-beam echosounders (EM2040) collect data on the aggregation morphology and behaviour of small pelagics
- Visual survey for to determine the abundance and distribution of jellyfish. Combined with analysis of trawl and plankton net caught individuals.
- Analysis of water samples to determine the composition and spatial distribution of pico- and nano- plankton populations, bacteria and CDOM
- Determine a survey plan to be conducted by unmanned surface vessel (USV) collecting acoustic density measurements within a pre-defined area. Carry out an acoustic inter-calibration exercise with the USV for data comparison purposes.

### 2.2.2 Survey design and area coverage

Survey coverage began in the southern Celtic Sea at 47°30'N (northern Biscay) and worked northwards to 58°30'N (northern Hebrides), including the Porcupine Bank (Figure 1). Area coverage was based on the distribution of catches from the previous surveys (e.g. O'Donnell *et al.* 2007 and 2011).

The survey area was stratified based on acoustic sampling effort strata and geographical stock boundaries. Transect start points were randomised within each stratum. Transect spacing was set at 15nmi (nautical miles) in open water areas and zigzag transects in the restricted Minch area. High intensity small scale surveys were carried out in specific areas of interest with a transect spacing of between 5-10nmi. Coverage extended from the 50 m contour to the shelf slope (250 m). An elementary distance sampling unit (EDSU) of 1nmi was used during the analysis of acoustic data during the main body of the survey area. In total the planned survey covered 5,096nmi using 66 transects relating to a total area coverage of 61,284nmi$^2$.

The survey was carried out from 04:00–00:00 each day to coincide with the hours of daylight when target species are most often observed in homogenous schools. During the hours of darkness schools disperse into mixed species scattering layers and are not readily available to acoustic sampling techniques.

Survey design and analysis methods for the WESPAS survey adhere to guidelines laid out in the Manual for International Pelagic Surveys (ICES, 2015).

## 2.3 Fisheries acoustics

### 2.3.1 EK60 Calibration

All frequencies of the Simrad EK60 were calibrated in Dunmanus Bay on June 11$^{th}$ at the start of the survey. A calibration was also conducted in Killary Harbour on July 22$^{nd}$ at the end of the survey. Calibration procedures followed methods laid out in Demer *et al.* (2015). The results of the calibration (38 kHz transducer) are provided in Table 1.

### 2.3.2 Acoustic array

Equipment settings for the acoustic equipment were determined before the start of the survey program and were based on established settings employed by FEAS on previous surveys (O'Donnell *et al.,* 2004).

Acoustic data were collected using the Simrad EK60 scientific echosounder. Simrad split-beam transducers are mounted within the vessel's drop keel and lowered to the working depth of 3.3m below the vessel's hull or 8.8 m sub surface. Four operating frequencies were used during the survey (18, 38, 120 and 200 kHz) for trace recognition purposes, with the 38 kHz data used to generate the abundance estimate.

While on survey track the vessel is normally propelled using DC twin electric motor propulsion system with power supplied from 1 main diesel engine, so in effect providing "silent cruising" as compared to normal operations. During fishing operations normal two-engine operations were employed to provide sufficient power to tow the net.

### 2.3.3 Acoustic data acquisition

Acoustic data were recorded onto the hard-drive of the processing unit. The "RAW files" were logged via a continuous Ethernet connection to the vessels server and the EK60 hard drive as a backup in the event of data loss. In addition, as a further back up a hard copy was stored on an external hard drive. Myriax Echoview® Echolog (Version 8) live viewer was used to display the echogram during data collection to allow the scientists to scroll through echograms noting the locations and depths of fish schools. A member of the scientific crew monitored the equipment continually. Time and location (GPS position) data was recorded for each transect within each strata. This log was used to monitor the time spent off track during fishing operations and hydrographic stations plus any other important observations.

### 2.3.4 Echogram scrutinisation

Acoustic data was backed up every 24 hrs and scrutinised using Echoview® (V 8) post processing software.

The RAW files were imported into Echoview for post-processing. The echograms were divided into transects. Echotraces belonging to one of the target species (herring, boarfish and horse mackerel) were identified visually and echo integration was performed on the enclosed regions. The echograms were analysed at a threshold of -70 dB and where necessary plankton was filtered out by thresholding at –65 dB.

Partitioning of echograms to identify individual schools was carried out to species level where possible and mixed scattering layers where it was not possible to identify mono-specific schools. For scattering layers or mixed schools containing target species the total NASC (Nautical Area Scattering Coefficient) was split using Target Strength (TS) to provide a species specific NASC value. This process was conducted within the StoX program.

The echogram scrutinisation process was carried out by a scientist experienced in scrutinising echograms and with the aid of accompanying trawl catch data.

The allocated echo integrator counts (NASC values) from these categories were used to estimate the herring numbers according to the method of Dalen and Nakken (1983).

The TS/length relationships used predominantly for the survey are those recommended by the acoustic survey planning group based at 38 kHz (ICES, 1994):

| | |
|---|---|
| *Herring* | TS = 20logL – 71.2 dB per individual (L = length in cm) |
| *Sprat* | TS = 20logL – 71.2 dB per individual (L = length in cm) |
| *Mackerel* | TS = 20logL – 84.9 dB per individual (L = length in cm) |
| *Horse mackerel* | TS = 20logL – 67.5 dB per individual (L = length in cm) |
| *Anchovy* | TS = 20logL – 71.2 dB per individual (L = length in cm) |

The TS length relationship used for boarfish is from Fassler et al (2013):

| | |
|---|---|
| *Boarfish* | TS = 20logL – 66.2 dB per individual (L = length in cm) |

The TS length relationship used for gadoids was a general physoclist relationship (Foote, 1987):

| | |
|---|---|
| *Gadoids* | TS = 20logL – 67.5 dB per individual (L = length in cm) |

### 2.3.5 Calculation of acoustic abundance

Acoustic data were analysed using the StoX software package recently adopted for WGIPS coordinated surveys (ICES 2016). A description of StoX can be found here: http://www.imr.no/forskning/prosjekter/stox/nb-no. Estimation of abundance from acoustic surveys within StoX is carried out according to the stratified transect design model developed by Jolly and Hampton (1990).

## 2.4 Biological sampling

A single pelagic midwater trawl with the dimensions of 85 m in length (LOA) and a fishing circle of 420 m was employed during the survey (Figure 24). Mesh size in the wings was 2.4 m through to 10 cm in the cod-end. The net was fished with a vertical mouth opening of approximately 25 m and was observed using a cable linked Simrad FS70 netsonde. Spread between the trawl doors was monitored using Scanmar distance sensors, all sensors being configured and viewed through a Scanmar Scanbas system.

All components of the catch from the trawl hauls were sorted and weighed; fish and other taxa were identified to species level. Fish samples were divided into species composition by weight. Species other than the herring were weighed as a component of the catch. Length frequency and length weight data were collected for each component of the catch. Length measurements of herring, boarfish, sprat and pilchard were taken to the nearest 0.5 cm below. Horse mackerel were taken to the nearest 1.0 cm below. Age, length, weight, sex and maturity data were recorded for individual herring, boarfish and horse mackerel within a random 50 fish sample from each trawl haul, where possible. All herring were aged onboard. The appropriate raising factors were calculated and applied to provide length frequency compositions for the bulk of each haul.

Decisions to fish on particular echo-traces were largely subjective and an attempt was made to target marks in all areas of concentration not just high density schools. No bottom trawl gear was used during this survey. However, the small size of the midwater gear used and its manoeuvrability in relation to the vessel power allowed samples at or below 1m from the bottom to be taken in areas of clean ground.

### 2.4.1 Herring stock identification

When possible, a sample of 120 herring (>23cm) are taken for morphometric and genetic analysis from herring in the Malin Shelf area (6a/7b, c). These fish are processed according to SGHERWAY procedures (ICES 2010).

## 2.5 Hydrography and biogeochemical data collection

Oceanographic stations were carried out during the survey at predetermined locations along the survey track using a calibrated SeaBird 911 rosette sampler. Data were collected from 1 m subsurface and 3-5 m above the seabed.

### 2.5.1 Hydrography and water sampling

Seawater samples were collected from typically 6 depths on the up cast of the profile by triggering Niskin bottles at predetermined depths related to the hydrography observed during the down cast. The CTD data comprises continuous downcast and up casts records of the pressure, temperature, conductivity (salinity), dissolved oxygen, chlorophyll fluorescence and turbidity. These data are processed according to GO-SHIP guidelines and incorporated into ODV files for the continuous downcast data and the discrete bottle data collected during the up cast.

Raw seawater samples were drawn from Niskin bottles mounted (n=21) on the ships CTD system. Typically six depths from just below the surface to 10 m above the maximum bathymetry depth were sampled. Raw samples were collected from the Niskin bottles into 1 ltr brown LDPE bottles. Sub samples were then obtained from the LDPEs.

### 2.5.2 CDOM measurements

Samples for the analysis of Colour Dissolved Organic Matter (CDOM) absorption were collected from the CTD cast directly from the Niskin bottles. They were then immediately filtered through a 0.2 µm syringe filter and part of the filtrate used for CDOM analysis onboard and the rest frozen at -20° C for later nutrient and FDOM analysis. CDOM measurements were performed using an Ocean Optics Maya spectrophotometer coupled to a 1m liquid wave guide capillary cell (LWCC), supplied by World Precision Instruments, and an Ocean Optics DH-mini light source.

The filtered samples frozen at -20° C will also be analysed, after thawing, back in the laboratory in Galway for nutrients and 3D EEM FDOM analysis (Horiba Aqualog). The 3D EEM FDOM dataset will be analysed using PARAFAC (Murphy et al., 2013) will allow the determination of independent fluorphore components in seawater which can be used to identify sources of FDOM from terrestrial or marine processes.

### 2.5.3 Nutrient sampling

Seawater samples are collected from the CTD and immediately filtered through 0.2 µm syringe filters. The filtrate is then frozen at -20 ℃ until analysis in the laboratory. For analysis in the laboratory samples are thawed overnight and then analysed for Nitrite, Nitrate, Phosphate and Silicate using specially adapted low volume methods based on standard green chemistry methods for nutrient analysis in seawater (García-Robledo et al., 2014; Koroleff, 1976; Murphy and Riley, 1962; Schnetger and Lehners, 2014).

#### 2.5.4 Bacteria, Heterotrophic nanoflagellates, Pico and nanoplankton abundance

An Accuri C6 flow cytometer was used to analyse raw and treated seawater samples to determine the presence and abundance of a number of species of micro planktonic organisms. This instrument employs a combination of the fluorescence and light scattering characteristics of the organisms present to identify and count the populations of the distinct species in each sample. Unfiltered seawater samples collected directly from the CTD are run on an Accuri C6 flow cytometer while at sea according to established protocols (Marie et al., 1997; Marie et al., 2014). An untreated raw sample is used to identify the phytoplankton by size and fluorescence, *Synechococcus* species can be identified at this step by their unique combination of cell size and phycoerythrin fluorescence. A second raw sample is treated with Lysotracker Green to determine heterotrophic nanoplanktonic protists (Rose et al., 2004). While a third sample is fixed with glutaraldehyde and then treated with the DNA stain Syber Green to enumerate marine bacteria and phytoplankton via the combination of chlorophyll fluorescence (red) and the DNA stain (green).

#### 2.5.5 Hyperspectral measurements

In order to more directly compare field data with satellite data, a pair of hyperspectral sensors were mounted above the bridge of the Celtic Explorer. The sensor pair incorporated an irradiance and radiance sensor for the purposes of determining the hyperspectral reflectance from the surface of the ocean for comparison to the reflectance measured by the ocean colour satellites.

Particulate absorption of fresh water and seawater can be determined by filtering a known amount of sample through a Glass Fiber Filter (GF/F) and measuring the particulate absorption coefficient $a_p(\lambda)$concentrated on the filter. This technique is called quantitative filter technique (QFT) and corrects for the pathlength amplification, an effect of scattering. Measurements were made shipboard using a QFT-1 filter holder (WPI) after filtering 200-1000 mL of seawater through a 25 mm GF/F filter. An Ocean Optics Maya spectrophotometer was coupled to the QFT-1 using 600 µm diameter fibre optical cable with a DH mini light source.

#### 2.5.6 Chlorophyll measurements

Water samples from Niskin bottles collected at near surface (5-6m depth) were filtered. Filtered samples were labelled and frozen for analysis in the laboratory after the survey.

### 2.6 Zooplankton and jellyfish sampling

#### 2.6.1 Zooplankton

Zooplankton sampling was carried out alongside CTD stations. A weighted 1 m diameter Hydro-bios ring net was used with a 200 µm mesh size and the net was fitted with a mechanical flow meter to determine the volume of water filtered. Vertical plankton tows were carried out to within 5 m of the seabed for stations where total depth was less than 100 m and to a 100 m maximum for all other stations depths.

Single tow stations samples were split in 50:50 for wet and dry processing. Sample splitting was carried out using a plankton sample splitter. The wet component was fixed for further analysis back at the lab. Fixing was carried using a 4% fix volume of buffered formalin. For replicate stations one sample was fixed in its entirety and the second was processed for dry weight.

Dry processing was carried out with each sample filtered through 2000 µm, 1000 µm and 125 µm sieves. For the largest gauge sample (2000 µm) including jellyfish and or krill volume displacement (ml) was measured using a graduated cylinder. For finer gauge samples (1000 and 125 µm) dry weight analysis was carried out. Samples were transferred to petri-dishes and dried onboard (70 °C oven) for a minimum of 24 hrs before sealing and freezer storage. Back in the lab dry weight analysis was carried out on defrosted frozen samples using a Sartorius MSE225S-000-DA fine scale balance (uncertainty of +/- 0.00016g).

### 2.6.2 Jellyfish

Jellyfish samples recovered from the directed zooplankton vertical trawls were separated from the dry weight and fixed component samples for further analysis. Once recovered, the cod end was washed into a 30 L bucket. Considering the rapid degradation and underrepresentation of many ctenophore species in fixed samples, those that were visible to the naked eye were enumerated and recorded separately by passing fresh zooplankton samples through a 180 µm sieve. The sample was then fixed in 4% formalin solution for further analysis in a laboratory on land. In total, 86 ring net stations were successfully deployed along the cruise track line (Figure 12).

A multinet (type midi) was deployed opportunistically to sample plankton in different depth strata during the survey. The sampling equipment has a computer-controlled opening and closing mechanism and electronic flow meters. An integrated pressure sensor allows constant supervision of the operating depth which is indicated at the display of the deck command unit. The multinet had a 300 µm net mesh size and a net opening of 50 cm. For each station, the water column was broken into 5 vertical depth strata and sampled via an oblique tow. Sampling lasted approximately 7 minutes per stratum and a minimum water volume of 100 m³ was filtered. Changes were made to the depth strata depending on the depth position of the migrating plankton layer at any one time, ensuring a single net bag filtered the diurnal plankton layer. The contents of the cod end buckets (x5) were placed in labelled 500 ml containers and fixed in 4% buffered formalin for taxonomic identification and enumeration back at the laboratory. Four multinet stations were undertaken. To evaluate the whether acoustic survey techniques can quantify abundances of gelatinous zooplankton in discrete depth strata, the multinet data will be compared with the single beam and multi-beam data that was collected during the multinet deployments.

By-caught gelatinous fauna collected in the pelagic survey trawl (Figure 24) were also recorded, weighed, measured and discarded after each haul. As the fishing was targeted and involved variable subsampling of catches, only qualitative data could be attained for gelatinous species using this large net. A total of 21 pelagic net hauls contained jellyfish taxa.

To quantify surface abundances of large jellyfish, surface counts of jellyfish from the bow of the Celtic Explorer were made during transits between sampling stations Observations were made from an elevated position from the bow of the ship, during day light hours (07:00–21:00 h). Jellyfish were identified to species level, and their numbers estimated per 5-min intervals using the following categories: 0, 1–10, 11–50, 51–100, 101–500, and >500 (jellyfish abundance estimates of much greater than 500 are impractical). Sample periods were 15 min long with 5 min breaks between successive samples. After three successive sample periods a 20 min break is taken, and after every 3–4 h a 1-h rest period is taken. Nearly 80 hours of visual surveys (933 surveys) were carried out over the duration of the research cruise.

## 2.7 Marine mammal and seabird surveys

### 2.7.1 Marine mammal abundance and distribution

The cetacean survey was conducted using a team of two marine mammal observers (MMOs), with one cetacean observer deployed per survey leg. To prevent MMO fatigue and optimise the validity of the data, survey effort was carried out in two-hour shifts, with a break of one hour between shifts.

Cetacean watches were conducted using a standard single platform line transect survey design while the vessel was travelling at a consistent speed and heading. When the vessel was stationary at oceanographic stations, cetacean watches were conducted using a standard single platform point sampling survey design. Visual watches were undertaken from the vessel's crow's nest, located 17.45m above sea level during all daylight hours, when weather conditions permitted. During periods of unfavourable weather conditions, observations were carried out from the bridge (10.63m above sea level).

Survey effort was concentrated in periods of sea state 6 or less, and in moderate or good visibility. Survey effort conducted outside of these parameters was conducted at the discretion of the observers. Survey effort for cetaceans was concentrated within an arc of 60° either side (i.e., to port and to starboard) of the vessel's track-line but all sightings to 90° both side of the track-line and further aft were also recorded. Searching for cetaceans was predominantly done with the naked eye, however, Nikon Prostaff 7 8x42 binoculars and a Canon EOS 7D DSLR camera with a Sigma 100-400mm zoom lens was used to confirm species identification and group size, and assess behaviour. Survey effort was also carried out during hauls and when at CTD stations.

The IFAW Logger 2000™ (IFAW, 2000) data collection software package was used to collect all positional, environmental and sightings data, and save it to a Microsoft Access database. Positional data was collected using a portable GPS receiver with a USB connection and recorded every 10 seconds.

Environmental data was recorded at least every 15-30 minutes, or sooner if there was a change in environmental conditions. Environmental data recorded included; wind speed, wind direction, sea state, swell, visibility, cloud cover and precipitation. All data entry was time stamped by Logger and saved in the Access database.

The distance of each sighting from the ship was estimated using a fixed interval range finder, while the bearing from the ship was estimated with an angle board. This data, along with data such as species identification, group size, composition, heading, sighting cues, surfacing interval, behaviour and any associations with birds or other cetaceans was also recorded on the time stamped Logger sighting record page. Where species identification could not be confirmed, sightings were recorded at an appropriate taxonomic/confidence level (i.e. probable, possible, unidentified whale, unidentified dolphin etc.). Auxiliary and incidental sightings were also recorded.

Ancillary data such as line changes, changes in survey activity (e.g. fishing/CTD cast) and fishing vessel activity were also recorded.

### 2.7.2 Seabird abundance and distribution

Surveys of seabirds at sea were conducted from the RV *Celtic Explorer* across 18 days between 10$^{th}$ and 27$^{th}$ June during Leg 1 and 19 days between 4$^{th}$ and 23$^{rd}$ July 2018 during Leg 2. While on transect, the ship travelled at an average speed of 10 knots, except when increased swell prohibited this. A standardised line transect method with sub-bands to allow correction for species detection bias and 'snapshots' to account for flying birds was used (following recommendations of Tasker et al. 1984; Komdeur et al. 1992; Camphuysen et al. 2004), as outlined below.

A single observer surveyed while the ship was travelling along transect lines during daylight hours, between 06:00 and 21:00 each day. Surveying ceased when the ship broke track (e.g. during fishing tows) or when stopped (e.g. during the deployment of the CTD and plankton nets). Environmental conditions, including wind force and direction, sea state, swell height, visibility, precipitation and cloud cover as well as the ship's speed and heading were noted at the start of each survey period and when significant changes occurred thereafter. No surveys were conducted out on deck in conditions greater than sea state six, when high swell made working on deck unsafe. During such periods of inclement weather or heavy seas, surveying was conducted from inside the bridge. Survey effort was also stopped when visibility was reduced to less than 300m due to heavy rain or sea fog.

The seabird observation platform varied between the bridge deck and the monkey island, which are 10m and 12m above the waterline respectively and provide a good view of the survey area. The monkey island was used during periods of calm weather while the bridge deck was utilised during windier conditions as more shelter was afforded there. The survey area was defined as a 300m wide band operated on one side (in a 90˚ arc from the bow) and 300m ahead of the ship. This survey band was subdivided (A = 0-50m from the ship, B = 50-100m, C = 100-200m, D = 200-300m, E = >300m) to subsequently allow correction of species differences in detection probability with distance from the observer. A fixed-interval range finder (Heinemann 1981) was used to check distance estimates for birds sitting on the water or those flying birds which were recorded during 'snapshot' counts. The area was scanned by eye, with binoculars used only to confirm species identification or count the number of birds present in a flock. All birds seen within the survey area were counted, and those recorded sitting on the water in survey bands A to D noted as 'in transect'. All flying birds within the survey area were also noted, but only those recorded during a 'snapshot' were regarded as 'in transect'. This method avoids overestimating bird numbers in flight (Tasker et al. 1984). The frequency of the snapshot scan was ship-speed dependent, such that they were timed to occur when the ship passed from one survey area to the next (every 300m). Any bird recorded within the survey area that was regarded as being associated with the survey vessel was noted as such (to be excluded from abundance and density calculations). Survey time intervals were set at one minute. Additional bird species observed outside the survey area or ad hoc counts of birds not occurring in the survey area were also recorded and added to the database for the research cruise, but are not included in abundance or density analysis.

During the 2018 survey, a series of point counts were made of seabirds associating with the vessel during fishing operations. These began as soon as the towed net began to appear near the surface of the water and finished once the fishing operation was complete, with the net back on board and any surplus fish cleared from the deck. Details such as date, time, location and details of the haul (gross tonnage, species present etc.) were noted for each of these point counts.

In this report, we present the daily total count data for each species along with the daily survey effort. It is envisaged that this data will be analysed such that seabird abundance (birds per km travelled), and seabird density (birds per $km^2$) will be mapped per ¼ ICES square (15˚ latitude x 30˚ longitude), allowing comparison to the results of previous seabird surveys in Irish waters (e.g. Hall et al. in press, Mackey et al. 2004, Pollock et al. 1997). Through further analysis, species-specific correction factors will be applied to birds observed on the water.

The binomial species names for the birds recorded are presented in the results section, for which taxonomy and nomenclature follows that of the Irish Rare Birds Committee (2015).

# 3 Results

## 3.1 Malin Shelf herring (6aS, 7b, c and 6aN south of 58°30'N)

### 3.1.1 Biomass and abundance

| Herring | Abund ('000) | Biomass (t) |
|---|---|---|
| Total stock (TSB) | 1,698,261 | 183,186 |
| Spawning stock (SSB) | 750,614 | 129,740 |

The Malin Shelf Herring total stock biomass (TSB) was 183,186 t and total stock numbers (TSN) was 1,698,261,000 (Table 3). The spawning stock biomass (SSB) was 129,740 t and spawning stock numbers (SSN) was 750,614,000. The CV for the survey was 0.28.

The Malin Shelf survey area was divided into 6 strata representing a total area coverage of 29,847 nmi$^2$ (Figure 2 & Table 5). A breakdown of herring stock abundance and biomass by age, maturity and stratum is detailed in Table 3 and Figures 3 & 4. The Malin Shelf survey time series is provided in Table 4.

### 3.1.2 Stock distribution

A total of 42 trawl hauls were carried out during the survey (Figure 1), with 4 hauls containing >50% herring by weight of catch within the Malin Shelf survey area (Table 2). A total of 228 echotraces were assigned to herring as compared to 161 in 2017.

Herring were distributed in five out of the six strata (Figure 2). There were no herring allocated to echotraces in the NW Coast Strata. A total of 117 EDSUs (1nmi. long) contained herring in the Malin Shelf survey area. This included a small number of high NASC value EDSUs, with areas of high density occurring to the southwest of St. Kilda and the southern Stanton Banks area (Figure 3). The area covered by the RV Celtic Explorer was similar to the 2017 survey. The area of 6aN to the north of 58°30'N was again covered by RV Scotia in 2018; the overall estimate of the survey for the stock assessment of herring in 6a will therefore be complete when both surveys are combined during WGIPS 2019. Herring were found further south than in 2017, with the distribution south of the 56 ˚N more similar to the historical distribution of herring found during this time series. Herring schools were predominantly located in pillars in close proximity to the seabed (Figure 11f and 11h), but there was evidence of 1-wr herring displaying more midwater behaviour (Figure 11g). Overall the stock was distributed throughout a slightly larger area compared to 2017 (Figure 3). Particularly encouraging was the distribution of 1- and 2-wr fish in the N Malin strata (South Stanton Bank). The seasonal distribution of herring during the survey period is most commonly observed in 3 particular regions; north of 57°N (west of the Hebrides), between 56-57°N (south and west of Barra Head) and south of 56°N (north and west of Donegal and

Stanton Bank). The survey in 2018 largely followed these norms, with the added distribution of 0-group herring found in the Minch strata area (Figure 11j).

### 3.1.3 Stock composition

A total of 681 herring were aged from survey samples with 3,231 length measurements and 782 length-weights recorded. Herring age samples ranged from 0-11 year olds (Table 3 & Figure 4). A further 360 herring were processed for morphometric and genetic analysis under SGHERWAY protocols (ICES 2010) in 2018; from hauls 35, 37 and 39. Genetic samples were taken from herring in haul #32, these fish were mainly <23cm, therefore SGHERWAY morphometric samples were not taken from this haul.

4-wr herring dominated the 2018 survey estimate representing around 30% of TSB and 22% of TSN (Table 3). 2-wr herring were ranked second representing 19% of TSB and 24% of TSN. The third most dominate age group was 5-wr herring contributing 14% to the TSB and 10% to TSN. Combined these three age classes represented 63% of TSB and 55% of TSN.

Maturity analysis of herring samples indicated overall 71% of fish were mature. In 2017, 99% of fish were mature. Maturity analysis by age class showed that 23% of 2 year old fish, 85% of 3 year old fish, and 97% of 4 year olds were mature, rising to 100% of fish of 6-wr and older (Table 3).

## 3.2 Boarfish

### 3.2.1 Biomass and abundance

| Boarfish | Abund ('000) | Biomass (t) |
|---|---|---|
| TSB estimate | 3,221,110 | 186,252 |
| SSB estimate | 3,041,284 | 184,235 |

Boarfish TSB (total stock biomass) and abundance (TSN) estimates were 186,252 t and 3,221,110,000 individuals (CV 19.9 %) respectively.

The boarfish survey area was divided into 6 strata representing a total area coverage of 56,403 nmi$^2$ (Figure 2). A breakdown of boarfish stock abundance and biomass by age, maturity and stratum is detailed in Table 6 & 7 and Figures 5 & 6. The boarfish survey time series is provided in Table 8.

### 3.2.2 Stock distribution

A total of 42 trawl hauls were carried out during the survey (Figure 1), with 15 hauls containing >50% boarfish (Table 2).

A total of 817 echotraces were assigned to boarfish as compared to 394 in 2017. Boarfish were observed in all survey strata (Table 7). The highest occurrence was in the Celtic Sea where over 42% of the total survey biomass was observed. Within the Celtic Sea the highest density of fish was observed in the southern survey area, south of 50°N and characterised by an area containing a high density of schools (Figure 9a). This pattern of distribution is similar to previous years (Figure 5). The west coast stratum contained the second largest biomass of 27% and again followed the previously observed pattern of abundance. The shelf area between 53-54°N including the porcupine Bank was an area of high abundance. Interestingly the southwest (between 51-52°N) saw fewer schools than in previous years. The distribution of boarfish to the northwest and north of Ireland was mainly restricted to the shelf edge (<180m). This year for the first time boarfish aggregations were observed during the Scottish summer herring survey extending the latitudinal range to north of 59°N (Steven O'Connell *Pers communication)*. Previously boarfish have not been observed during this survey further north than 57°30N.

#### 3.2.3 Stock composition

A total of 945 boarfish were aged from survey samples in addition to 4,807 length measurements and 2,234 length-weights recorded. Boarfish age samples ranged from 1-15+ years (Table 6 & Figure 6). Age structure of the stock was determined using an established age length key.

The 10 year age class dominates the 2018 estimate contributing over 20.4% of TSB and 19.4% of TSN (Table 6). The 11 group and 15+ year age class ranked second and third respectively representing over 12.9% of TSB and 9.3 and 10.5% of TSN each to the overall biomass. The fourth ranked group was the 12 year olds 10.8% to the TSB and 8.2% to TSN. Combined, the 10, 15+ and 11 year age classes represent 46.1% of TSB and 39.2% of TSN.

Maturity analysis of boarfish samples indicated 98.8% of observed biomass was composed of mature individuals (94.4% for abundance). Maturity analysis by age class showed that 33% of 3 year old fish were mature, rising to 100% for fish four years and older (Table 6).

### 3.3 Horse mackerel

#### 3.3.1 Biomass and abundance

| Horse mackerel | Abund ('000) | Biomass (t) |
|---|---|---|
| TSB estimate | 540,422.0 | 92,931.9 |
| SSB estimate | 503,903.0 | 89,050.4 |

Horse mackerel TSB (total stock biomass) and abundance (TSN) estimates were 92,931.9 t and 540,422,000 individuals (CV 36.8%) respectively.

The horse mackerel survey area was composed of 8 strata relating to an area coverage of 61,285 nmi$^2$ as shown in Figure 2. A breakdown of horse mackerel stock abundance and biomass by age, maturity and stratum is detailed in Tables 9 & 10 and Figures 7 & 8.

#### 3.3.2 Stock distribution

A total of 42 trawl hauls were carried out during the survey (Figure 1), with 3 hauls containing >50% horse mackerel out of 20 containing horse mackerel overall (Table 2).

A total of 198 echotraces were assigned to horse mackerel. Horse mackerel were widely distributed along the west coast or Ireland, the Porcupine Bank and Celtic Sea where the bulk of the standing stock was located (Figure 7). Observations of horse mackerel along the west coast and Celtic Sea were comparable to 2016-17 in terms of distribution but the number and overall acoustic density was lower. The 2017 estimate of abundance was bolstered by a large single aggregation of spawning fish that contributed over 24% to the total biomass. No aggregations of this scale were observed this year. The west coast stratum remains a significant contributor to the TSB contributing 58% in 2018 followed by the Celtic Sea (35%). Schools of horse mackerel were frequently observed on the seabed and most often over a rocky substrate and along the west coast were often observed in areas containing boarfish (Figure 11b).

### 3.3.3 Stock composition

A total of 541 horse mackerel were aged from survey samples in addition to 1,466 length measurements and 750 length-weights recorded. Horse mackerel age samples ranged from 1-17 years (Table 9 & Figure 8). Age structure of the stock was determined using an age length key from constructed from the previous years aged survey samples.

The 3 year age class dominated this year's survey estimate representing over 32.2% of TSB and 45% of TSN (Table 9). The 7 year age class ranked second representing over 14.5% of TSB and 9.1% of TSN (Table 9). Fourteen year old fish were ranked third contributing 11.2% to TSB and 5.0% to TSN. Combined these three age classes represented 57.9% of TSB and 59.2% of TSN.

Maturity analysis of horse mackerel samples indicated 95.8% of the TSB was mature. Maturity analysis by age class showed that 99% of 5 year old fish were mature, rising to 100% for fish three years and older (Table 9).

## 3.4 Celtic Sea herring (7g and j)

### 3.4.1 Biomass and abundance

| CS Herring | Abund ('000) | Biomass (t) |
|---|---|---|
| Total stock | 132,419.0 | 22,745.5 |
| Spawning stock | 129,088.8 | 22,248.5 |

The estimate of Celtic Sea (CS) herring TSB (total stock biomass) and abundance (TSN) estimates were 22,745.5 t and 132,419,000 individuals (CV 74%) respectively.

The herring survey area was composed of two strata, one broad scale (Celtic Sea) and one high intensity (NW Bank and Celtic Deep). The former represented an area of over 26,626 nmi$^2$ and was surveyed using a transect spacing of 15 nmi, whereas the latter was surveyed using a higher intensity of 4-6 nmi and covered an area of 2,644 nmi. A breakdown of CS herring stock abundance and biomass by age, maturity and stratum is detailed in Tables 12 & 13 and Figures 9 & 10.

### 3.4.2 Stock distribution

CS herring were observed in two regions during the survey. A single high density school of herring was observed south of the Jones's Bank (Figure 11d). During the 2017 survey, a small number of individual herring were also observed around this area, occurring as a by-catch. Numbers were insufficient; both acoustically and biologically to produce a reliable estimate of abundance for the wider Celtic Sea stratum and this is reflected in the high CV value for the combined estimate (74%).

Herring were also observed on the Northwest Bank and in the western Celtic and were composed in the main of a higher number (n=41) of low density schools spread over a wide area (Figures 9 & 11e).The distribution of herring around this area is spatially consistent with observations from this survey in 2017. The Celtic Deep region was surveyed using the USV while the northwest Bank was survey by the Celtic Explorer.

Genetic samples were taken from both locations where herring were located and will be used in part of a larger project to determine the identity of stock components.

### 3.4.3 Stock composition

A total of 213 CS herring were aged from survey samples in addition to 337 length measurements and 122 length-weights recorded. CS Herring age samples ranged from 1-9 years (Table 12 & 13 and Figure 10). Age structure of the stock was determined from aged otoliths.

Five, four and six winter ring fish dominated the total estimate (Table 12). The age structure of fish was found to very between strata, with a wider range of age classes encountered around the Celtic Deep stratum (Figure 10).

## 3.5 Hydrography and biogeochemical sampling

### 3.5.1 CTD sampling

In total 86 CTD casts were carried out (Figure 12). Horizontal temperature and salinity maps for the survey area are provided for depths 5 m, 20, 40 and 60 m in Figures 13-16 respectively.

Surface waters were strongly influenced by the strong and persistent spell of clear and sunny weather experienced before during and after the survey. Thermocline depth varied by location but ranged between 20-45m across the spatial extent of the survey. Strong tidally mixed areas to the north of Ireland and those influenced by riverine inputs such as the River Shannon in the southwest of Ireland are visible as areas of cooler near surface conditions (Figure 14). At 50m depth cooler waters ring the Irish coastline and Celtic Sea (Figure 15) whereas warmer Atlantic origin water is visible to the west of Ireland and Scotland and denotes the boundary region of the Irish Shelf front. Seafloor temperatures show a similar pattern with a ring of cooler, less saline water ringing western Ireland and the Celtic Sea (Figure 16). Warmer, southern water masses in the Celtic Sea are clearly visible with near uniform seabed temperature along the west coast of Ireland and Scotland.

Comparing herring distribution with hydrographic conditions herring are observed in areas of cooler water (Figure 17). Salinity is variable for most areas where herring were located, but temperature was in the most part cooler than the surrounding area. The exception to this observation occurs in the southern Celtic Sea where a herring school was observed and identified (by trawling) in waters exceeding 11 °C at the seafloor.

For boarfish thermal preference appears as important as salinity (Figure 18). The greatest density of boarfish is aligned with full strength seawater and off the west coast this occurs on the oceanic side of the Irish Shelf Front. The pattern of distribution changes relative to temperature and depth along the west coast and Porcupine Bank where boarfish take a midwater position below the thermocline.

Horse mackerel (Figure 19) distribution appears to follow a similar pattern to that of boarfish in that full strength seawater is the preferred habitat with a variable temperature distribution profile from north to south.

### 3.5.2 CDOM measurements

CDOM sampling was undertaken at all of the 86 hydrographic stations during the survey. Analysis of samples is underway.

### 3.5.3 Nutrient sampling

Samples were collected from all of the 86 hydrographic stations during the survey. Analysis of samples is underway.

### 3.5.4 Pico/nano plankton sampling

Sampling of pico and nano plankton communities was carried out at all of the 86 oceanographic stations during the survey. The software that controls the Accuri C6 flow cytometer is able to graphically display the optical and physical characteristics of the organisms present in any sample. The forward scattering of incident light gives an indication on the size of an organism whereas the side scatter of the light relates to the shape of that particular organism. The three fluorescence sensors are set to respond to different colours of fluorescence, orange, green and red, and help to differentiate between the photosynthetic pigments that are unique to the individual species of plankton that are being studied. Further analysis is currently on-going.

### 3.5.5 Hyperspectral analysis

### 3.5.6 Chlorophyll measurements

The frozen filters previously measured onboard for the QFT-1 measurements were analysed in the laboratory for chlorophyll a (b & c) concentrations after extraction with 90% acetone using a Telfon grinder and subsequent measurement of the solution absorbance using an Ocean Optics Flame spectrophotometer with a low volume 10 cm pathlength cell and DT-mini light source. The concentration of chlorophyll a was calculated using the trichromatic equation of Jeffrey and Humphrey (1975).

Generally good agreement was achieved between the satellite data collected data and data collected at sea (Figure 21). A more detailed analysis of this dataset will be conducted over the next few months.

## 3.6 Zooplankton biomass and jellyfish abundance

### 3.6.1 Zooplankton

Plankton samples were collected at 83 stations during the survey. Species composition analysis is currently underway using chemically fixed samples. Dry weight biomass for zooplankton on a per station basis is shown in Figure 18.

Zooplankton biomass (dry weight) by station was higher overall than compared to the same time in 2016 (Figure 18). Zooplankton distribution, as determined from dry weight analysis, showed a relatively uniform distribution throughout the survey with little sign of the spatial patchiness observed in 2016. This defined difference between years is difficult to explain over such a short sampling time frame (2 successive years) but given the sampling effort and intensity this has the potential to provide important information on plankton distribution that was previous lacking.

### 3.6.2 Jellyfish

Preliminary data for this method are provided below. On leg 1, a total of 2,424 jellyfish were enumerated from visual surveys. The three most abundant species included the hydrozoan *Aqueora sp.* (1,235 observations), the ctenophore *Beroe sp.* (633 observations) and the pleustonic hydrozoan *Velella velella* (435 observations). The highly venomous lion's mane jellyfish *Cyanea capillata* was only spotted 19 times in the Celtic sea using this method. On the second leg, 2,577 jellyfish were observed in total. The most abundant was the cosmopolitan *Aurelia aurita* (1805 spotted), followed by the lion's mane jellyfish *C. capillata* (310) and the blue jellyfish *Cyanea lamarckii* (152 spotted). Further data processing will allow the quantitative description of surface jellyfish abundance along the cruise track line. Results are not available for other jellyfish methodologies as they require several months of laboratory analysis for taxonomic enumeration.

## 3.7 Marine mammals and seabirds

### 3.7.1 Visual abundance survey

In total, 272 hours and 18 minutes of survey effort was conducted over the course of the WESPAS 2018 survey, 132 hours and 45 minutes of survey effort was conducted on Leg 1, while 139 hours and 33 minutes of survey effort was conducted on Leg 2 of the survey. In total, 255 hours and 25 minutes of survey effort were conducted using a line transect methodology, while 16 hours and 52 minutes of effort were conducted using the point sampling methodology. Environmental data was collected a total of 1,698 times during the survey.

A total of 160 sightings, were recorded throughout the survey. This includes 47 sightings recorded as auxiliary sightings and 38 sightings recorded as incidental sightings. From the total 160 sightings, marine mammals accounted for 122 sightings. Decomposing marine mammal carcases were also sighted on two occasions. The remaining 36 sightings consisted of other marine megafauna. The marine mammal sightings included; 2 whale species, 6 dolphin species, 1 seal species, and a number of sightings which could not be identified to species level. Mixed species sightings were recorded on two separate occasions.

Of the 160 sightings, 159 were recorded while conducting line transects, while 1 was recorded while conducting point sampling. A list of the species encountered can be seen in Table 14, and the distribution of the sightings can be seen in Figures 22 & 23.

Minke whales (*Balaenoptera* acutorostrata) were the most frequently encountered species accounting for 39 sightings (24% of all sightings) comprising of 41 individuals in total.

Common dolphins (*Delphinus delphis*) were the second most frequently observed and most abundant species. Common Dolphins were encountered on 29 occasions, accounting for 18% of all sightings. These sightings consisted of a total of 436 individuals (46% of all encountered individuals).

The ocean sunfish (*Mola mola*) were the third most frequently encountered species, and the most frequently encountered species of marine megafauna excluding marine mammals. The sunfish were spotted on 25 separate occasions, accounting for 15% of all sightings. Each sighting consisted of a lone individual (3% of encountered individuals).

A number of elasmobranch species were encountered including; blue shark (*Prionace glauca*), porbeagle shark (*Lamna nasus*) and basking shark (*Cetorhinus maximus*). Leatherback turtles (*Dermochelys coriacea*) were encountered on two occasions.

### 3.7.2 Seabird abundance and distribution

The cumulative total of dedicated seabird survey effort during WESPAS 2018 comes to 156 hours and 16 minutes (9376 minutes) across 37 days. The cumulative total of individual seabirds recorded comes to 11151 of 26 species, of which 7,481 were noted as ‘off survey’ (outside of dedicated survey time or associating with the vessel, including during fishing operations point counts) and as such will be excluded from future analysis of abundance and density.

Leg 1: A total of 65 hours and 45 minutes (3,945 minutes) of dedicated seabird surveys was conducted across 18 days between 10$^{th}$ and 27$^{th}$ June 2018. A cumulative total of 4,434 individual seabirds of 18 species were recorded, of which 3,662 were noted as ‘off survey’ (Table 16).

Leg 2: A total of 90 hours and 31 minutes (5,431 minutes) of dedicated seabird surveys was conducted across 19 days between 4$^{th}$ and 23$^{rd}$ July 2018. A cumulative total of 6717 individual seabirds of 24 species were recorded, of which 3,819 were noted as ‘off survey’ (Table 16).

In addition, daily totals for six species of migrant terrestrial birds recorded on or around the vessel are also presented (Table 16).

# 4 Discussion and Conclusions

## 4.1 Discussion

The objectives of the survey were carried out successfully and as planned. Good weather conditions dominated during the survey allowing for extended marine mammal and seabird survey effort. No weather induced downtime was recorded.

Malin Shelf herring distribution was concentrated in an area to the west of the Hebrides in 6aN and in the southern and western Stanton Bank area in 6aS (Figure 3). There was an 18% increase in the SSB in 2018 compared to 2017 (O'Donnell et al 2017). There were good signs of young herring (1- and 2-wr fish) distributed in 6aS and in the area to the east and west of the Butt of Lewis in particular. 0-wr herring were found in the Minch, distributed near the surface in mixed schools that were dominated by 0-wr sprat. This was in contrast to 2016 and 2017 where there were relatively few herring observed south of 56°N in 6aS or 7b, c and no 0- and 1- wr fish. The age profile of survey samples in 2018 is encouraging in the context of cohort tracking for the assessment; 4 year old herring dominated the stock (30% in terms of biomass, and 22% in terms of abundance). The survey was dominated by 3-wr fish in 2017. In 2016, there was a much more even distribution of year classes. The CV estimate for the 2018 survey is lower than in 2017 (0.28 compared to 0.45); this is more comparable to previous years in the time-series.

The distribution of boarfish was comparable to 2017 and earlier years in the time series with the exception of the northern region. The northern distribution of the stock was observed to extend almost continuously, albeit it in low abundance, northward of 59°N north. Distribution was reported to continue up to 60°N as reported by the RV *Scotia*. Although important, these schools were not considered to be significant to the overall estimate. Overall, the acoustic density and number of echotraces of boarfish was lower than observed in 2017 for the same trawl and acoustic sampling effort. The age profile of dominant cohorts was different to 2017 and this is likely attributed to the use of an age length key to assign ages to biological samples rather than the aging of actual survey collected otoliths collected that year.

Horse mackerel were distributed in comparable regions along the Irish west coast, Porcupine Bank and Celtic Sea. Geographical distribution was thus comparable to previous surveys but the number and acoustic density of aggregations was lower than in 2017. That said the total stock estimate is more in line with 2016 than 2017. However, more years of survey effort are required for trends to emerge. The age composition of the stock in 2018 was strongly influenced by the 3 year old component, something not evident in 2017 as two year old fish. Seven and fourteen year class remain dominant.

Observations of Celtic Sea herring survey were continued in 2018. Combining RV and ASV platform effort allowed for a wider area to be covered. Acoustic inter-calibration of instruments from each platform allowed the data to be combined to produce an overall estimate of abundance. Containment issues still exist and thus limit the reliability of estimates of abundance for this stock. The stock identity of larger, older individuals in the southern survey area remains to be determined from genetic sampling. The presence of feeding herring around the Celtic Deep across years highlights the importance of this area to a portion of the stock throughout the summer and autumn period prior to the spawning migration.

Hydrographic conditions in surface waters were as to be expected during the summer months with warmer waters dominating more southern latitudes and well stratified water masses with a strong thermocline. The start of the survey coincided with the start of a prolonged period of hot and sunny weather. Thermocline depth ranged from 20-55m depending on location, with the lower limit observed areas with strong tidal mixing. Below the thermocline and at seafloor, Ireland appeared to be ringed by an area of cool water close to the coast with a district boundary front. Seafloor temperatures along the shelf area on the oceanic side of the front appeared almost uniform along the west coast of Ireland and Scotland with temperatures over 10 °C in the northernmost latitudes. Interestingly herring were encountered only within the cool water ribbon to the west of Scotland and not in the warmer regions. Boarfish and horse mackerel, as open ocean species, were primarily distributed in full seawater conditions and on the oceanic side of the Irish shelf front regardless of temperature or latitude.

## 4.2 Conclusions

- Malin Shelf herring biomass was ~18% higher in 2018 compared to 2017 ($SSB_{2018}$ =130,000 t; $SSB_{2017}$ = 107,000 t). The CV on the survey was lower in 2018 (0.28) when compared with 2017 (0.46); the CV in 2018 is comparable to previous years in the time series
- Malin Shelf herring TSB (total stock biomass) and abundance (TSN) estimates were 183,188 t and 1,698,300,000 individuals respectively
- Herring were distributed further south in 2018 compared to 2017, with some herring south of 56°N, particularly young fish (1- and 2-wr). There was very little herring distributed south of 56°N in both 2016 and 2017.
- The dominant age class of herring in the 2018 survey was 4-wr fish (30% TSB, and 22% TSN). This compares well with the 2017 survey, showing good cohort tracking; the dominant age class in the 2017 survey was 3-wr fish (43% TSB).
- The three most dominant year classes of herring were 2-, 4- and 5-wr fish and together represented over 63% of the TSB in 2018.The three most dominant year classes in 2017 were 3-, 4- and 6-wr fish, representing over 78% of the TSB.
- 1-wr herring were found in the survey for the first time since 2015. There were also 0-wr herring found mixed in surface schools of sprat in the Minch.
- Herring were found in very small numbers off the west coast of Ireland for the first time in many years on this survey.
- Boarfish distribution showed a similar pattern to previous years. The number of schools and acoustic density was lower than in 2017.
- Boarfish TSB (total stock biomass) and abundance (TSN) estimates were 186,252 t and 3,221,110,000 individuals (CV 19.9%) respectively.
- The northern distribution of boarfish continued north of the Hebrides outside of the core survey area and schools were observed the RV *Scotia*. However, it is important to note that the number and acoustic density were considered low.
- Horse mackerel biomass is considered a reliable estimate of the standing stock in 2018 given comparable survey effort and area coverage. Improvements are required to ensure greater containment in the southern boundary and western approaches to the Channel.
- Horse mackerel TSB (total stock biomass) and abundance (TSN) estimates were 92,931 t and 540,422,000 individuals (CV 36.8%) respectively.
- The positive influence of the 3 year class of horse mackerel is notable.
- Celtic Sea herring were observed around the banks in the eastern Celtic Sea as well as in the mid Celtic Sea. The size and age of schools observed, although low in number were notably different. Containment remains an issue for reliable estimates abundance during this survey. However, it is intended that this will be further developed to provide an additional measure of this stock.

## 5 Recommendations

- Continuation of the south to north work flow to align with surveys in the south (PELGAS- France) and north (HERAS- Scotland) and provide synoptic estimates of abundance for a multiple species.
- Real time aging of horse mackerel survey samples to provide within year age estimates of survey data.
- Research the possibility of egg counts from plankton samples (WP2) as a means to track spawning, and peak spawning events by geographic region for boarfish and horse mackerel.
- To further develop this survey more ship-time is required. As the survey is observing not only target species for the focal component but also the distribution of other species that are also surveyed during the year, specifically Celtic Sea herring.
- Westward extension of some transects in the northwest of the survey area to ensure boarfish stock containment. This may also require some extra survey days.

## 6 Acknowledgements

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# 7 References

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# 8 Tables and Figures

**Table 1.** Calibration report: Simrad EK60 echosounder at 38 kHz.

## Echo Sounder System Calibration Report

| | | | |
|---|---|---|---|
| Vessel : | RV Celtic Explorer | Date : | 10.06.18 |
| Echo sounder : | Drop Keel | Locality : | Dunmanus Bay |
| Type of Sphere : | WC 38.1 | $TS_{Sphere}$: -42.2 dB | Depth(Sea floor) : 36 m |

Calibration Version 2.1.0.12

**Comments:**
Dunmanus Bay Survey Start

**Reference Target:**

| | | | |
|---|---|---|---|
| TS | -42.2 dB | Min. Distance | 18.0m |
| TS Deviation | 5 dB | Max. Distance | 22.0m |

**Transducer: ES38B Serial No.**

| | | | |
|---|---|---|---|
| Frequency | 38000 Hz | Beamtype | Split |
| Gain | 26.65 dB | Two Way Beam Angle | -20.6 dB |
| Athw. Angle Sens. | 21.90 | Along. Angle Sens. | 21.90 |
| Athw. Beam Angle | 7.09 deg | Along. Beam Angle | 7.03 deg |
| Athw. Offset Angle | -0.01 deg | Along. Offset Angl | -0.05 deg |
| SaCorrection | -0.58 dB | Depth | 8.80 m |

**Transceiver: GPT 38 kHz 009072033933 1 ES38B**

| | | | |
|---|---|---|---|
| Pulse Duration | 1.024 ms | Sample Interval | 0.190 m |
| Power | 2000 W | Receiver Bandwidth | 2.43 kHz |

**Sounder Type:**
ER60 Version 2.4.3

**TS Detection:**

| | | | |
|---|---|---|---|
| Min. Value | -50.0 dB | Min. Spacing | 100% |
| Max. Beam Comp. | 6.0 dB | Min. Echolength | 80% |
| Max. Phase Dev. | 8 | Max. Echolength | 180% |

**Environment:**

| | | | |
|---|---|---|---|
| Absorption Coeff. | 10.2 dB/km | Sound Velocity | 1481.5 m/s |

**Beam Model results:**

| | | | |
|---|---|---|---|
| Transducer Gain = | 25.29 dB | SaCorrection = | -0.60 dB |
| Athw. Beam Angle = | 7.04 deg | Along. Beam Angle | 6.97 deg |
| Athw. Offset Angle = | -0.02 deg | Along. Offset Angl | -0.06 deg |

**Data deviation from beam model:**
RMS = 0.23 dB
Max = 0.79 dB No. = 237 Athw. = 2.8 deg Along = 3.3 deg
Min = -0.74 dB No. = 212 Athw. = -3.7 deg Along = -0.4 deg

**Data deviation from polynomial model:**
RMS = 0.22 dB
Max = 0.74 dB No. = 211 Athw. = -4.8 deg Along = -0.6 deg
Min = -0.70 dB No. = 212 Athw. = -3.7 deg Along = -0.4 deg

**Comments :**
SE wind F3, strong tide
**Wind Force :** F4 **Wind Direction :** N
**Raw Data File:** C:\Program files\Simrad\Scientific\EK60\Data\Calibration\WESPAS 2018\Drop Keel
**Calibration File:** C:\Program files\Simrad\Scientific\EK60\Data\Calibration\WESPAS 2018\Drop Keel

**Calibration :** Ciaran O'Donnell

**Table 2.** Catch table from directed trawl hauls.

| No. | Date | Lat. N | Lon. W | Time | Bottom (m) | Target btm (m) | Bulk Catch (Kg) | Boarfish % | Mackerel % | Herring % | H Mack % | Others^ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 11.06.18 | 50.34 | -7.25 | 10:58 | 104 | 104 | 450 | 4.5 | 1.8 | 13.9 | 0.2 | 79.6 |
| 2 | 13.06.18 | 47.72 | -6.60 | 10:01 | 170 | 150 | 109 | 2.3 | | | 51.9 | 45.8 |
| 3 | 14.06.18 | 48.23 | -8.57 | 13:50 | 174 | 174 | 235 | 39.4 | 3.3 | | | 57.3 |
| 4 | 14.06.18 | 48.23 | -7.91 | 19:14 | 180 | 180-155 | 193 | 86.5 | | | 13.0 | 0.5 |
| 5 | 15.06.18 | 48.47 | -6.27 | 11:04 | 130 | 130 | 225 | | 14.5 | | 71.4 | 14.1 |
| 6 | 16.06.18 | 48.48 | -9.50 | 08:36 | 184 | 184-160 | 600 | 84.7 | | | 2.3 | 13.0 |
| 7 | 16.06.18 | 48.73 | -8.98 | 17:51 | 160 | 160-120 | 160 | 99.6 | | | 0.2 | 0.3 |
| 8 | 17.06.18 | 48.99 | 7.58 | 05:27 | 146 | 125-100 | 27 | | 30.1 | 5.4 | 53.3 | 11.2 |
| 9 | 17.06.18 | 49.00 | -7.49 | 07:28 | 134 | 134-110 | 172 | 94.7 | 0.5 | 0.5 | | 4.3 |
| 10 | 18.06.18 | 49.24 | -10.98 | 10:00 | 173 | 173-153 | 85 | 79.7 | | | 0.4 | 19.9 |
| 11 | 18.06.18 | 49.24 | -10.48 | 13:57 | 143 | 125-100 | 700 | 99.1 | 0.7 | | 0.3 | 0.0 |
| 12 | 19.06.18 | 49.49 | -8.90 | 18:01 | 124 | 85-60 | 79 | 99.7 | | | | 0.3 |
| 13 | 20.06.18 | 49.75 | -10.46 | 13:26 | 139 | 30-50 | 400 | | 83.9 | | 16.1 | 0.0 |
| 14 | 21.06.18 | 50.00 | -8.53 | 15:50 | 131 | 131-115 | 235 | | 0.3 | | | 99.7 |
| 15 | 22.06.18 | 50.25 | -10.46 | 09:47 | 143 | 100-75 | 300 | 87.5 | 2.0 | | 9.8 | 0.8 |
| 16 | 22.06.18 | 50.25 | -9.29 | 16:51 | 132 | 132 | 3,000 | | 3.6 | | | 96.4 |
| 17 | 23.06.18 | 50.50 | -7.73 | 10:05 | 107 | 90 | 145 | | 1.9 | 11.2 | | 86.9 |
| 18 | 24.06.18 | 50.75 | -9.75 | 09:58 | 115 | 85-65 | 3 | | 6.7 | | | 93.3 |
| 19 | 25.06.18 | 50.86 | -6.53 | 15:55 | 93 | 80-60 | 650 | | | | | 100.0 |
| 20 | 27.06.18 | 51.76 | -10.98 | 11:20 | 158 | 75 | 7 | | 43.4 | | 24.6 | 32.0 |
| 21 | 04.07.18 | 52.51 | -10.89 | 11:06 | 127 | 100-127 | 80 | 0.3 | | 1.6 | | 98.1 |
| 22 | 05.07.18 | 53.01 | -10.74 | 05:23 | 130 | 125-130 | 51 | 0.6 | | 0.2 | | 99.2 |
| 23 | 05.07.18 | 53.26 | -11.43 | 17:06 | 146 | 125-145 | 7 | 37.1 | 53.0 | | 6.5 | 3.4 |
| 24 | 06.07.18 | 53.51 | -11.41 | 06:17 | 175 | 50-100 | 1,000 | 91.0 | 0.2 | | 8.8 | 0.0 |
| 25 | 08.07.18 | 53.51 | -13.72 | 05:40 | 210 | 60-90 | 1,000 | 93.8 | 6.0 | | | 0.2 |
| 26 | 09.07.18 | 54.01 | -10.82 | 08:20 | 183 | 75-100 | 1,500 | 95.6 | | 0.6 | 3.5 | 0.3 |
| 27 | 09.07.18 | 54.26 | -10.36 | 15:33 | 100 | 75-100 | 500 | | 0.1 | | | 99.9 |
| 28 | 10.07.18 | 54.76 | -10.31 | 11:51 | 125 | 100-125 | 171 | 73.0 | 17.6 | 0.1 | 0.1 | 9.2 |
| 29 | 10.07.18 | 55.02 | -10.01 | 16:59 | 115 | 75-115 | 1,500 | 95.9 | 0.5 | | 1.3 | 2.2 |
| 30 | 11.07.18 | 55.52 | -9.01 | 13:30 | 100 | 80-100 | 182 | 10.4 | 0.3 | 0.1 | 9.4 | 79.7 |
| 31 | 11.07.18 | 55.52 | -7.71 | 20:07 | 65 | 40-65 | 12 | | | | | 100.0 |
| 32 | 12.07.18 | 55.54 | -7.77 | 04:46 | 69 | 20-40 | 4,000 | | | 99.0 | | 1.0 |
| 33 | 13.07.18 | 55.77 | -9.14 | 09:15 | 134 | 110-134 | 160 | 59.8 | 8.1 | | 29.2 | 2.8 |
| 34 | 13.07.18 | 56.02 | -8.58 | 14:32 | 145 | 125-145 | 29 | | 8.8 | 23.7 | | 67.6 |
| 35 | 14.07.18 | 56.52 | -8.66 | 19:34 | 140 | 120-140 | 306 | | 35.4 | 64.5 | | 0.1 |
| 36 | 15.07.18 | 56.77 | -8.71 | 12:56 | 122 | 115-122 | 8 | | | | | 100.0 |
| 37 | 16.07.18 | 57.27 | -8.52 | 07:42 | 144 | 115-140 | 117 | | 7.7 | 90.3 | | 2.1 |
| 38 | 16.07.18 | 57.52 | -9.23 | 16:16 | 180 | 90-110 | 139 | 99.5 | | | 0.3 | 0.2 |
| 39 | 17.07.18 | 57.77 | -8.89 | 11:20 | 152 | 110-152 | 1,250 | | 0.9 | 97.5 | | 1.6 |
| 40 | 19.07.18 | 58.54 | -7.25 | 06:21 | 97 | 50-100 | 320 | | 55.7 | 35.5 | | 8.8 |
| 41 | 19.07.18 | 58.54 | -5.64 | 12:36 | 140 | 120-140 | 500 | | | 0.8 | | 99.2 |
| 42 | 20.07.18 | 57.30 | -6.30 | 15:51 | 81 | 0-40 | 84 | | | 7.2 | | 92.8 |

**Table 3.** Malin Shelf herring stock estimate 2018 (6aS, 7bc and 6aN (south of 58°30'N).

| | Age (years) | | | | | | | | | | | | | Numbers | Biomass | Mn Wt | Mature |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Length | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12+ | (*10-3) | (t) | (g) | (%) |
| 5.5 | 9586 | - | - | - | - | - | - | - | - | - | - | - | - | 9586 | | | 0 |
| 6 | 61349 | - | - | - | - | - | - | - | - | - | - | - | - | 61349 | | | 0 |
| 6.5 | 115030 | - | - | - | - | - | - | - | - | - | - | - | - | 115030 | | | 0 |
| 7 | 49846 | - | - | - | - | - | - | - | - | - | - | - | - | 49846 | | | 0 |
| 7.5 | 24923 | - | - | - | - | - | - | - | - | - | - | - | - | 24923 | | | 0 |
| 8 | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | | | 0 |
| 8.5 | 3834 | - | - | - | - | - | - | - | - | - | - | - | - | 3834 | | | 0 |
| 9 | \| | - | - | - | - | - | - | - | - | - | - | - | - | 0 | | | 0 |
| 9.5 | \| | - | - | - | - | - | - | - | - | - | - | - | - | 0 | | | 0 |
| 10 | \| | - | - | - | - | - | - | - | - | - | - | - | - | 0 | | | 0 |
| 10.5 | \| | - | - | - | - | - | - | - | - | - | - | - | - | 0 | | | 0 |
| 11 | \| | - | - | - | - | - | - | - | - | - | - | - | - | 0 | | | 0 |
| 11.5 | \| | - | - | - | - | - | - | - | - | - | - | - | - | 0 | | | 0 |
| 12 | \| | - | - | - | - | - | - | - | - | - | - | - | - | 0 | | | 0 |
| 12.5 | \| | - | - | - | - | - | - | - | - | - | - | - | - | 0 | | | 0 |
| 13 | \| | - | - | - | - | - | - | - | - | - | - | - | - | 0 | | | 0 |
| 13.5 | \| | - | - | - | - | - | - | - | - | - | - | - | - | 0 | | | 0 |
| 14 | \| | - | - | - | - | - | - | - | - | - | - | - | - | 0 | | | 0 |
| 14.5 | \| | - | - | - | - | - | - | - | - | - | - | - | - | 0 | | | 0 |
| 15 | \| | - | - | - | - | - | - | - | - | - | - | - | - | 0 | | | 0 |
| 15.5 | \| | 1284 | - | - | - | - | - | - | - | - | - | - | - | 1284 | | | 0 |
| 16 | \| | 8068 | - | - | - | - | - | - | - | - | - | - | - | 8068 | 291.9 | 36.18 | 0 |
| 16.5 | \| | 26772 | - | - | - | - | - | - | - | - | - | - | - | 26772 | 1086.5 | 40.58 | 0 |
| 17 | \| | 53633 | - | - | - | - | - | - | - | - | - | - | - | 53633 | 2226.4 | 41.51 | 0 |
| 17.5 | \| | 53062 | - | - | - | - | - | - | - | - | - | - | - | 53062 | 2444.5 | 46.07 | 0 |
| 18 | \| | 54239 | - | - | - | - | - | - | - | - | - | - | - | 54239 | 2786.7 | 51.38 | 0 |
| 18.5 | \| | 65759 | - | - | - | - | - | - | - | - | - | - | - | 65759 | 3659.5 | 55.65 | 0 |
| 19 | \| | 42590 | 2462 | - | - | - | - | - | - | - | - | - | - | 45052 | 2719.2 | 60.36 | 0 |
| 19.5 | \| | 34646 | - | - | - | - | - | - | - | - | - | - | - | 34646 | 2239.5 | 64.64 | 0 |
| 20 | \| | 36564 | 6611 | - | - | - | - | - | - | - | - | - | - | 43175 | 3106.6 | 71.95 | 0 |
| 20.5 | \| | 6091 | 30269 | - | - | - | - | - | - | - | - | - | - | 36360 | 2738.8 | 75.33 | 0 |
| 21 | \| | 11286 | 17917 | - | - | - | - | - | - | - | - | - | - | 29203 | 2446.8 | 83.79 | 19 |
| 21.5 | \| | 1774 | 31122 | - | - | - | - | - | - | - | - | - | - | 32896 | 3113.3 | 94.64 | 9 |
| 22 | \| | - | 35701 | - | - | - | - | - | - | - | - | - | - | 35701 | 3589.5 | 100.54 | 0 |
| 22.5 | \| | - | 47818 | - | - | - | - | - | - | - | - | - | - | 47818 | 4918.8 | 102.87 | 5 |
| 23 | \| | - | 68001 | 2450 | - | - | - | - | - | - | - | - | - | 70451 | 7887.3 | 111.96 | 29 |
| 23.5 | \| | - | 50475 | 9823 | - | - | - | - | - | - | - | - | - | 60298 | 7085.4 | 117.51 | 17 |
| 24 | \| | - | 27927 | 6372 | 1398 | 1774 | - | - | - | - | - | - | - | 37471 | 4856.1 | 129.6 | 87 |
| 24.5 | \| | - | 7759 | 12698 | 7142 | - | - | - | - | - | - | - | - | 27599 | 3666.9 | 132.86 | 75 |
| 25 | \| | - | 10460 | 9250 | 22271 | - | - | - | - | - | - | - | - | 41981 | 5858.5 | 139.55 | 83 |
| 25.5 | \| | - | 2647 | 21656 | 28277 | 5083 | - | - | - | - | - | - | - | 57663 | 8625.1 | 149.58 | 93 |
| 26 | \| | - | - | 27383 | 48058 | 6585 | 820 | - | - | - | - | - | - | 82846 | 13087.2 | 157.97 | 100 |
| 26.5 | \| | - | - | 13555 | 47902 | 19485 | - | - | - | - | - | - | - | 80942 | 14073.8 | 173.88 | 99 |
| 27 | \| | - | - | 3188 | 60333 | 37803 | 1074 | - | - | - | - | - | - | 102398 | 18567.3 | 181.32 | 98 |
| 27.5 | \| | - | - | 3189 | 48507 | 24002 | - | 9136 | - | - | - | - | - | 84834 | 15988.6 | 188.47 | 100 |
| 28 | \| | - | - | 2891 | 29339 | 24105 | 11430 | 10544 | 3147 | - | - | - | - | 81456 | 16328.3 | 200.45 | 100 |
| 28.5 | \| | - | - | - | 12064 | 12537 | 13657 | 11194 | 3259 | 2015 | - | - | - | 54726 | 11331.5 | 207.06 | 100 |
| 29 | \| | - | - | - | 6211 | 6164 | 6759 | 15670 | 3431 | 1229 | 1282 | - | - | 40746 | 8887.9 | 218.13 | 100 |
| 29.5 | \| | - | - | - | 2632 | - | 9982 | 8982 | 5535 | - | - | - | - | 27131 | 6081 | 224.13 | 100 |
| 30 | \| | - | - | - | - | - | - | 3998 | 1414 | 4920 | - | - | - | 10332 | 2291.8 | 221.84 | 100 |
| 30.5 | \| | - | - | - | - | - | - | - | - | - | - | 3511 | - | 3511 | 793.6 | 226 | 100 |
| 31 | \| | - | - | - | - | - | - | - | - | - | - | 602 | - | 602 | 133 | 221 | 100 |
| 32 | \| | - | - | - | - | - | - | - | - | - | - | 1038 | - | 1038 | 276.2 | 266 | 100 |
| TSN (1000) | 264568 | 395768 | 339168 | 112454 | 314133 | 137539 | 43721 | 59524 | 16786 | 8164 | 1282 | 5151 | | 1698261 | | | |
| TSB (t) | | 21464.2 | 35763 | 17223.8 | 54787.7 | 25648.5 | 9149.3 | 12289 | 3591.5 | 1786.1 | 281.4 | 1202.8 | | | 183187.5 | | |
| Mean length (cm) | | 18.3 | 22.54 | 25.44 | 26.71 | 27.28 | 28.59 | 28.64 | 28.96 | 29.48 | 29 | 32 | | | | | |
| Mean weight (g) | | 54.41 | 105.44 | 153.16 | 174.41 | 186.48 | 209.27 | 206.46 | 213.96 | 218.78 | 219.6 | 266 | | | | 127.89 | |
| SSB (t) | | 307.03563 | 7789.5909 | 14571.6424 | 53387.77 | 25216 | 9149.49 | 12289 | 3591.5 | 1786.1 | 281.53 | 1370.2 | | | 129740 | | |
| % mature | | 1 | 22 | 85 | 97 | 98 | 100 | 100 | 100 | 100 | 100 | 100 | | | | | |

**Table 4.** Malin Shelf herring survey time series 2008-2018. Survey coverage: - ^ 6aS & 7bc; * 6aS, 6aN & 7b; ** 6a & 7bc; ***6aS, 7bc & 6aN (south of 58°30'N).

| Age | 2008^ | 2009^ | 2010* | 2011* | 2012* | 2013* | 2014* | 2015** | 2016* | 2017*** | 2018*** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | - | - | - | - | - | - | - | - | - | - | 264.6 |
| 1 | 6.1 | 416.4 | 524.8 | 82.1 | 608.3 | - | 1,115.4 | 4.9 | - | - | 395.8 |
| 2 | 75.9 | 81.3 | 504.3 | 202.5 | 451.5 | 96.2 | 214.7 | 162.1 | 9.7 | 11.0 | 339.2 |
| 3 | 64.7 | 11.4 | 133.3 | 752.0 | 444.6 | 254.3 | 166.3 | 291.7 | 102.3 | 273.4 | 112.5 |
| 4 | 38.4 | 15.1 | 107.4 | 381.0 | 516.1 | 265.8 | 380.0 | 580.7 | 91.4 | 111.0 | 314.1 |
| 5 | 22.3 | 7.7 | 103.0 | 110.8 | 180.3 | 78.7 | 352.1 | 487.3 | 91.4 | 71.6 | 137.5 |
| 6 | 26.2 | 7.1 | 83.7 | 124.0 | 115.4 | 26.9 | 125.0 | 513.4 | 58.2 | 94.4 | 43.7 |
| 7 | 9.1 | 7.5 | 57.6 | 118.4 | 116.9 | 18.5 | 18.9 | 143.9 | 46.5 | 28.0 | 59.5 |
| 8 | 5.0 | 0.4 | 35.3 | 70.7 | 83.8 | 10.8 | 9.7 | 33.4 | 2.7 | 9.9 | 16.8 |
| 9 | 3.7 | 0.9 | 17.5 | 41.6 | 56.3 | 4.1 | 4.7 | - | 0.5 | 2.6 | 8.2 |
| 10+ | - | - | - | 25.6 | 42.0 | 1.2 | - | 8.3 | - | - | 6.4 |
| TSN (mil) | 251.4 | 547.7 | 1,566.9 | 1,908.7 | 2,615.0 | 756.6 | 2,386.8 | 2,225.5 | 402.8 | 601.8 | 1,698.3 |
| TSB (t) | 44,611.0 | 46,460.0 | 192,979.0 | 313,305.0 | 397,797.0 | 118,946.0 | 294,200.0 | 449,343.0 | 70,745.0 | 107,900.0 | 183,187.5 |
| SSB (t) | 43,006.0 | 20,906.0 | 170,154.0 | 284,632.0 | 325,835.0 | 92,700.0 | 200,200.0 | 425,392.0 | 69,269.5 | 106,657.0 | 129,740.0 |
| CV | 34.2 | 32.2 | 24.7 | 22.4 | 22.8 | 21.5 | 28.6 | 28.6 | 31.3 | 46.6 | 28.3 |

**Table 5.** Malin Shelf herring spawning stock biomass and abundance by strata 2018

| Strata | Name | Area (nmi$^2$) | Transects | Abundance ('000) | Bio (t) |
|---|---|---|---|---|---|
| 1 | Minches | 3105 | 9 | 318989 | 2,494 |
| 2 | W Hebrides | 6148 | 7 | 657518 | 108,588 |
| 3 | SW Hebrides | 5030 | 4 | 233196 | 36,301 |
| 4 | NW Coast | 2251 | 2 | 0 | 0 |
| 5 | W Coast | 10212 | 12 | 9731 | 750 |
| 6 | N Malin | 3102 | 2 | 477546 | 35053.9 |
| | **Total** | 29,847 | 36 | 1,696,980 | 183,186 |

**Table 6.** Total boarfish stock estimate.

| Length (cm) | Age (years) 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15+ | Unknown | Numbers (000's) | Biomass (t) | Mn Wt (g) | Mature (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 25.2 | | | | | | | | | | | | | | | | 12612 | 25.2 | 2 | 0 |
| 5.5 | 18.9 | | | | | | | | | | | | | | | | 6306 | 18.9 | 3 | 0 |
| 6 | | | | | | | | | | | | | | | | | | | | |
| 6.5 | 113.5 | | | | | | | | | | | | | | | | 18918 | 113.5 | 6 | 0 |
| 7 | 253.8 | | | | | | | | | | | | | | | | 32514 | 253.8 | 8 | 0 |
| 7.5 | 50.4 | | | | | | | | | | | | | | | | 6306 | 50.4 | 8 | 0 |
| 8 | | 239.3 | | | | | | | | | | | | | | | 20016 | 239.3 | 12 | 0 |
| 8.5 | | 72.4 | 438.9 | | | | | | | | | | | | | | 36738 | 511.3 | 14 | 0 |
| 9 | | | 543.8 | | | | | | | | | | | | | | 34446 | 543.8 | 16 | 0 |
| 9.5 | | | 400.2 | | | | | | | | | | | | | | 21652 | 400.2 | 18 | 0 |
| 10 | | 96.7 | 287.8 | | | | | | | | | | | | | | 18384 | 384.5 | 21 | 100 |
| 10.5 | | | 381.2 | 275.7 | | | | | | | | | | | | | 25384 | 656.9 | 26 | 100 |
| 11 | | | | 1515.1 | 863.7 | | | | | | | | | | | | 82695 | 2378.8 | 29 | 100 |
| 11.5 | | | | 210.3 | 1465 | 3350.5 | | | | | | | | | | | 153631 | 5025.9 | 33 | 100 |
| 12 | | | | | 770.4 | 1107 | 3344.9 | 73.8 | | | | | | | | | 143938 | 5296.1 | 37 | 100 |
| 12.5 | | | | | 442.7 | 754.7 | 3167.9 | 1876.2 | | | | | | | | | 148018 | 6241.5 | 42 | 100 |
| 13 | | | | | | 603 | 4236 | 3415.3 | 568.5 | 215.3 | | | | | | | 185259 | 9038.1 | 49 | 100 |
| 13.5 | | | | | | | 3788.2 | 3950.8 | 7993.9 | 75.8 | | | | | | | 301310 | 15808.7 | 52 | 100 |
| 14 | | | | | | | | 87.2 | 7087.2 | 17155.4 | 106.4 | | | | 76.6 | | 425790 | 24512.7 | 58 | 100 |
| 14.5 | | | | | | | | 260.5 | 370.7 | 20311.9 | 2791.8 | 3049.2 | 1439.7 | 1135.9 | 1945.8 | | 485278 | 31305.4 | 65 | 100 |
| 15 | | | | | | | | | | 302.2 | 21042.2 | 536.9 | 2878.6 | 2785.5 | 5245.7 | | 458932 | 32791.1 | 71 | 100 |
| 15.5 | | | | | | | | | | | | 16500.5 | | | 7485.5 | | 305973 | 23986 | 78 | 100 |
| 16 | | | | | | | | | | | | | 11599.3 | | 4459.8 | | 187800 | 16059.1 | 86 | 100 |
| 16.5 | | | | | | | | | | | | | | 5610.4 | 1932.8 | | 80135 | 7543.2 | 94 | 100 |
| 17 | | | | | | | | | | | | | | | 2617.7 | | 25313 | 2617.7 | 103 | 100 |
| 17.5 | | | | | | | | | | | | | | | | 275.2 | 2572 | 275.2 | 107 | 100 |
| 18 | | | | | | | | | | | | | | | | | | | | |
| 18.5 | | | | | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | | | | | |
| 19.5 | | | | | | | | | | | | | | | 19.6 | | 297 | 19.6 | 66 | 100 |
| 20 | | | | | | | | | | | | | | | | | | | | |
| 20.5 | | | | | | | | | | | | | | | 155.3 | | 892 | 155.3 | 174 | 100 |
| TSN ($10^{-3}$) | 76655 | 31222 | 115019 | 68265 | 106679 | 165920 | 320741 | 197749 | 293448 | 624683 | 339214 | 264184 | 198415 | 116492 | 299850 | 2572 | 3221110 | | | |
| TSB (t) | 461.9 | 408.4 | 2051.9 | 2001.1 | 3541.8 | 5815.2 | 14537 | 9663.8 | 16020.2 | 38060.6 | 23940.5 | 20086.5 | 15917.6 | 9531.8 | 23938.8 | 275.2 | | 186252 | | |
| Mean length (cm) | 6.47 | 8.4 | 9.28 | 10.97 | 11.54 | 11.83 | 12.72 | 13.11 | 13.71 | 14.25 | 14.93 | 15.31 | 15.63 | 15.7 | 15.57 | 17.5 | | | | |
| Mean weight (g) | 6.03 | 13.08 | 17.84 | 29.31 | 33.2 | 35.05 | 45.32 | 48.87 | 54.59 | 60.93 | 70.58 | 76.03 | 80.22 | 81.82 | 79.84 | 107 | | | 57.82 | |
| % mature* | 0 | 24 | 33 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | | | | |
| SSB | 0.0 | 96.7 | 669.0 | 2001.1 | 3541.8 | 5815.2 | 14537.0 | 9663.8 | 16020.3 | 38060.6 | 23940.4 | 20086.6 | 15917.6 | 9531.8 | 23938.8 | 275.2 | 184235.0 | | | |

**Table 7.** Boarfish biomass and abundance by strata.

| Name | Area (nmi²) | Transects | Abun ('000) | Bio (t) |
|---|---|---|---|---|
| W Hebrides | 4,690.8 | 8 | 274,422 | 17,407 |
| S Hebrides | 1,980.8 | 4 | 146,345 | 7,361 |
| W Coast | 14,726.6 | 20 | 908,062 | 50,201 |
| Porcupine Bk | 5,734.6 | 6 | 365,017 | 27,824 |
| Celtic Sea | 26,626.7 | 16 | 1,422,426 | 78,530 |
| Celtic Deep | 2,644.2 | 8 | 104,837 | 4,929 |
| **Total** | 56,403.7 | 62 | 3,221,109 | 186,252.2 |

**Table 8.** Boarfish survey time series. Note: 2016 CV estimate calculated using StoX.

| Age (Yrs) | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|
| 0 | - | - | - | - | - | - | - | - |
| 1 | 5.0 | 21.5 | - | - | 198.5 | 4.6 | 110.9 | 76.7 |
| 2 | 11.6 | 10.8 | 78.0 | - | 319.2 | 35.7 | 126.7 | 31.2 |
| 3 | 57.8 | 174.1 | 1,842.9 | 15.0 | 16.6 | 45.5 | 344.6 | 115 |
| 4 | 187.4 | 64.8 | 696.4 | 98.2 | 34.3 | 43.6 | 367.3 | 68.3 |
| 5 | 436.7 | 95.0 | 381.6 | 102.3 | 80.0 | 6.0 | 156.0 | 106.7 |
| 6 | 1,165.9 | 736.1 | 253.8 | 104.9 | 112.0 | 10.0 | 209.0 | 165.9 |
| 7 | 1,184.2 | 973.8 | 1,056.6 | 414.6 | 437.4 | 169.0 | 493.1 | 320.7 |
| 8 | 703.6 | 758.9 | 879.4 | 343.8 | 362.9 | 112.6 | 468.3 | 197.7 |
| 9 | 1,094.5 | 848.6 | 800.9 | 341.9 | 353.5 | 117.6 | 397.2 | 293.4 |
| 10 | 1,031.5 | 955.9 | 703.8 | 332.3 | 360.0 | 96.6 | 285.8 | 624.7 |
| 11 | 332.9 | 650.9 | 263.7 | 129.9 | 131.7 | 17.0 | 120.9 | 339.2 |
| 12 | 653.3 | 1,099.7 | 202.9 | 104.9 | 113.0 | 32.0 | 82.1 | 264.1 |
| 13 | 336.0 | 857.2 | 296.6 | 166.4 | 174.0 | 48.7 | 74.4 | 198.4 |
| 14 | 385.0 | 655.8 | 169.8 | 88.5 | 108.0 | 18.3 | 220.4 | 116.5 |
| 15+ | 3,519.0 | 6,353.7 | 1,464.3 | 855.1 | 1,195.0 | 400.1 | 931.0 | 302.4 |
| **TSN** ($10^{-3}$) | 11,104 | 14,257 | 9,091 | 3,098 | 3,996 | 1,157 | 4,387 | 3,221 |
| **TSB (t)** | 670,176 | 863,446 | 439,890 | 187,779 | 232,634 | 69,690 | 223,860 | 186,252 |
| **SSB (t)** | 669,392 | 861,544 | 423,158 | 187,654 | 226,659 | 69,103 | 218,810 | 184,235 |
| **CV** | 21.2 | 10.6 | 17.5 | 15.1 | 17.0 | 16.4 | 21.9 | 19.9 |

**Table 9**. Horse mackerel stock estimate.

| Length | Age (years) | | | | | | | | | | | | | | | | | | | | | | Numbers | Biomass | Mn Wt | Mature |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (cm) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | Unknown | (000's) | (t) | (g) | (%) |
| 11 | | | | | | | | | | | | | | | | | | | | | | | 125 | | | 0 |
| 12 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | | | | | | | | 5.5 | 262 | 5.5 | 21 | 0 |
| 14 | | | | | | | | | | | | | | | | | | | | | | 7.3 | 262 | 7.3 | 28 | 0 |
| 15 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 | | 49.4 | | | | | | | | | | | | | | | | | | | | | 1048 | 49.4 | 47.11 | 0 |
| 18 | | | | | | | | | | | | | | | | | | | | | | 22.9 | 441 | 22.9 | 52 | 0 |
| 19 | 63.2 | 113.1 | | | | | | | | | | | | | | | | | | | | | 2830 | 176.3 | 62 | 0 |
| 20 | | 351.9 | | | | | | | | | | | | | | | | | | | | | 4363 | 351.9 | 81 | 100 |
| 21 | | 1441.8 | | | | | | | | | | | | | | | | | | | | | 16587 | 1441.8 | 87 | 50 |
| 22 | | 4289 | 422.5 | | | | | | | | | | | | | | | | | | | | 46985 | 4711.5 | 100 | 81 |
| 23 | | 592.9 | 10029 | 70.4 | | | | | | | | | | | | | | | | | | | 95236 | 10692.6 | 112 | 91 |
| 24 | | 51.6 | 10579 | 768.4 | 222.3 | | | | | | | | | | | | | | | | | | 93979 | 11621 | 124 | 98 |
| 25 | | | 8366.6 | 1201.8 | 50.8 | 75.2 | | | | | | | | | | | | | | | | | 70202 | 9694.4 | 138 | 93 |
| 26 | | | 291.7 | 5889.6 | 356.1 | | | | | | | | | | | | | | | | | | 41741 | 6537.4 | 157 | 98 |
| 27 | | | 48.6 | 5199.5 | 490.7 | 517.4 | 223.1 | 69.7 | | | | | | | | | | | | | | | 36858 | 6549 | 178 | 100 |
| 28 | | | 257.2 | 477.9 | 258.4 | 276.5 | 1349.5 | | | | | | | | | | | | | | | | 13507 | 2619.5 | 194 | 100 |
| 29 | | | | | 338.7 | 271.9 | 782.1 | 99.8 | | | | | | | | | | | | | | | 6695 | 1492.4 | 223 | 100 |
| 30 | | | | | 171.9 | 168.8 | 2488.5 | | | | | | | | | | | | | | | | 11400 | 2829.3 | 248 | 100 |
| 31 | | | | | | 59.8 | 1798.1 | | | | | | | | | | | | | | | | 7110 | 1857.9 | 261 | 100 |
| 32 | | | | | | 187.3 | 2457.4 | 487.3 | | | | 170.6 | | | | | | | | | | | 11246 | 3302.5 | 294 | 100 |
| 33 | | | | | | | 921.6 | 851.5 | 53.5 | | 166.5 | 209.9 | | 383.8 | | | | | | | | | 8166 | 2586.8 | 316.78 | 100 |
| 34 | | | | | | | 2605.3 | 2868.1 | 1543.8 | | | 2008.2 | 2145 | 2277.7 | | | | | | | | | 39210 | 13448.1 | 342.98 | 100 |
| 35 | | | | | | | 818 | | | | 305.3 | | | 639.8 | | | | | | | | | 4682 | 1763.1 | 376.56 | 100 |
| 36 | | | | | | | | | | 610.5 | | 132 | 30.3 | 4422.4 | | | | | | | | | 13878 | 5195.1 | 374.33 | 100 |
| 37 | | | | | | | | | 2186.2 | | 77.4 | | 855.9 | 2202.9 | | | | | | | | | 12325 | 5322.4 | 431.84 | 100 |
| 38 | | | | | | | | | | | | | | 83.5 | | | | | | | | | 203 | 83.5 | 411 | 100 |
| 39 | | | | | | | | | | | | | | 196.9 | | | | | | | | | 394 | 196.9 | 499.95 | 100 |
| 40 | | | | | | | | | | | | | | 209.8 | | | | | | | | | 425 | 209.8 | 494 | 100 |
| 41 | | | | | | | | | | | | | | | | | 164 | | | | | | 262 | 163.5 | 624 | 100 |
| 42 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TSN ($10^{-3}$) | 1015 | 72408 | 243280 | 85252 | 10495 | 7562 | 49329 | 13338 | 10047 | 1511 | 1547 | 7356 | 8462 | 27469 | | | 262 | | | | | 1090 | 540422 | | | |
| TSB (t) | 63.2 | 6889.6 | 29995 | 13608 | 1888.9 | 1556.9 | 13444 | 4376.4 | 3783.5 | 610.5 | 549.1 | 2520.6 | 3031.2 | 10417 | | | 164 | | | | | 35.8 | | 92931.9 | | |
| Mean length (cm) | 19 | 21.59 | 23.89 | 26.14 | 26.82 | 28.17 | 31.07 | 33.18 | 35.57 | 36 | 34.56 | 33.84 | 34.69 | 35.62 | | | 41 | | | | | 15 | | | | |
| Mean weight (g) | 62.29 | 95.15 | 123.29 | 159.61 | 179.98 | 205.88 | 272.53 | 328.1 | 376.59 | 404 | 355.09 | 342.69 | 358.22 | 379.23 | | | 624 | | | | | 37 | | | 172 | |
| % mature* | 0 | 75 | 94 | 98 | 99 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | | | 100 | | | | | 0 | | | | |
| SSB | 0 | 5,137 | 28,209 | 13,384 | 1,874 | 1,552 | 13,444 | 4,376 | 3,784 | 611 | 549 | 2,521 | 3,031 | 10,417 | | | 164 | | | | | 0 | 89050.4 | | | |

**Table 10.** Horse mackerel biomass and abundance by strata.

| Name | Area (nmi²) | Transects | Abun ('000) | Bio (t) |
|---|---|---|---|---|
| W Hebrides | 4,690.8 | 8 | 2,800 | 356 |
| S Hebrides | 1,980.8 | 4 | 1,116 | 141.8 |
| N Stanton | 1,522.3 | 3 | 9,552 | 1212.9 |
| S Stanton | 2,323.8 | 5 | 7,917 | 1003.1 |
| W Coast | 14,726.6 | 20 | 323,584 | 53,733 |
| Porc Bank | 5,734.6 | 6 | 14,689 | 3,043 |
| Celtic Sea | 26,626.7 | 17 | 176,882 | 32,727 |
| Celtic Deep | 2,121.5 | 8 | 3,884 | 715 |
| Minch | 1,557.6 | 9 | - | - |
| **Total** | 61,284.8 | 80 | 540,424 | 92,932 |

**Table 11.** Horse mackerel survey time series.

| Age (Yrs) | 2016 | 2017 | 2018 |
|---|---|---|---|
| 0 | - | - | - |
| 1 | 1.1 | 11.7 | 1.015 |
| 2 | 100.2 | 181.8 | 72.408 |
| 3 | 4.9 | 147 | 243.28 |
| 4 | 43.5 | 45.4 | 85.252 |
| 5 | 19.0 | 16.2 | 10.495 |
| 6 | 7.6 | 46 | 7.562 |
| 7 | 40.6 | 113 | 49.329 |
| 8 | 66.6 | 67.7 | 13.338 |
| 9 | 8.5 | 25.4 | 10.047 |
| 10 | 1.8 | 33.2 | 1.511 |
| 11 | 9.5 | 32.6 | 1.547 |
| 12 | 10.6 | 37.7 | 7.356 |
| 13 | 4.7 | 37.6 | 8.5 |
| 14 | 21.1 | 160.8 | 27.5 |
| 15 | 6.5 | 8.6 | - |
| 16 | 1.6 | 5.2 | - |
| 17 | 5.3 | - | 0.262 |
| 18 | - | - | - |
| 19 | - | - | - |
| 20 | - | - | - |
| 21 | 1.1 | - | - |
| **TSN ($10^{-3}$)** | 354.5 | 969,655 | 540,422 |
| **TSB (t)** | 69,267 | 228,116 | 92,931.90 |
| **SSB (t)** | 65,194 | 227,395.6 | 89,050.40 |
| **CV** | 42.0 | 25.5 | 36.8 |

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**Table 12**. Celtic Sea herring stock estimate.

| Length (cm) | Age (years) 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | Unknown | Numbers ($10^{-3}$) | Biomass (t) | Mn Wt (g) | Mature (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11.5 | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | |
| 12.5 | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | | |
| 13.5 | | | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | | |
| 14.5 | | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | | |
| 15.5 | | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | | |
| 16.5 | | | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | | | |
| 17.5 | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | | |
| 18.5 | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | |
| 19.5 | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | |
| 20.5 | | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | |
| 21.5 | | | | | | | | | | | | 10.6 | 125 | 10.6 | 85 | 0 |
| 22 | | | 63.4 | | | | | | | | | | 689 | 63.4 | 92 | 0 |
| 22.5 | | | 43.2 | 46.4 | | | | | | | | | 961 | 89.6 | 93 | 0 |
| 23 | | 12.6 | 108.7 | | 19.6 | | | | | | | | 1377 | 140.9 | 102 | 66 |
| 23.5 | | | 102.5 | 120.6 | 13.9 | | | | | | | | 2321 | 237 | 102 | 69 |
| 24 | | | 83.5 | 201.3 | 25.5 | | | | | | | | 2701 | 310.4 | 115 | 81.25 |
| 24.5 | | | 136.1 | 165.8 | 222.5 | | | | | | | | 4198 | 524.4 | 125 | 85 |
| 25 | | | | 193.4 | 133.7 | | | | | | | | 2517 | 327.1 | 130 | 85.72 |
| 25.5 | | | 34.7 | 142.7 | 170.7 | 163.7 | | | | | | | 3661 | 511.9 | 140 | 95 |
| 26 | | | 928.8 | 6.8 | 271.8 | 62.3 | 48.9 | 27.7 | | | | | 9020 | 1346.4 | 149 | 100 |
| 26.5 | | | | 56.7 | 3441.4 | 164.8 | 109.5 | 104.3 | 82.4 | | | | 24521 | 3959 | 161 | 100 |
| 27 | | | | 768 | 3871 | 57.3 | 277.3 | 105.4 | 24.3 | | | | 29398 | 5103.3 | 174 | 100 |
| 27.5 | | | | | 1757.9 | 1634.3 | 258.2 | 45.7 | 15.7 | | | | 20481 | 3711.8 | 181 | 100 |
| 28 | | | | | 1218.6 | | 102.1 | 45.4 | 43.6 | | | | 7375 | 1409.6 | 191 | 100 |
| 28.5 | | | | | | 1253 | 91.3 | | | | | | 6656 | 1344.3 | 202 | 100 |
| 29 | | | | | | | 1334 | | | | | | 6234 | 1334 | 214 | 100 |
| 29.5 | | | | 2292.2 | | | | | | | | | 10059 | 2292.2 | 228 | 100 |
| 30 | | | | | | | | | 29.6 | | | | 125 | 29.6 | 236 | 100 |
| 30.5 | | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | | |
| 31.5 | | | | | | | | | | | | | | | | |
| TSN ($10^{-3}$) | | 125.0 | 11556.0 | 22209.0 | 65532.0 | 18550.0 | 11243.0 | 1971.0 | 1107.0 | | | 125 | 132419 | | | |
| TSB (t) | | 12.6 | 1501.0 | 3993.8 | 11146.8 | 3335.3 | 2221.3 | 328.5 | 195.5 | | | 10.6 | | 22745.5 | | |
| Mean length (cm) | | 23.0 | 24.8 | 27.2 | 26.8 | 27.6 | 28.2 | 27.0 | 27.3 | | | 21.5 | | | | |
| Mean weight (g) | | 101.0 | 129.9 | 179.8 | 170.1 | 179.8 | 197.6 | 166.7 | 176.6 | | | 85 | | | 171.77 | |
| % mature* | | 66 | 86 | 95 | 99 | 100 | 100 | 100 | 100 | | | | | | | |
| SSB ('000 t) | | 8.3 | 1287.3 | 3811.7 | 11069.3 | 3326.4 | 2221.3 | 328.5 | 195.6 | | | | 22248.5 | | | |

**Table 13.** Celtic Sea herring total stock biomass and total abundance by strata.

| Name | Area (nmi²) | Transects | Abun ('000) | Bio (t) |
|---|---|---|---|---|
| Celtic Sea | 26,626.7 | 15 | 99,738 | 18,175 |
| C Deep/NW Bank | 2,644.2 | 11 | 32,681 | 4,570 |
| **Total** | 29,270.9 | 26 | 132,419 | 22,745.5 |

**Table 14.** Marine mammal and megafauna sightings, counts and group size ranges for cetaceans sighted during the survey (includes on and off effort).

| Common Name | Species name | No. of Sightings | No. of individuals | Group Size |
|---|---|---|---|---|
| **Atlantic white-sided dolphin** | *Lagenorhynchus acutus* | 1 | 3 | 3 |
| **Bottlenose dolphin** | *Tursiops truncatus* | 5 | 105 | 8-45 |
| **Common dolphin** | *Delphinus delphis* | 28 | 336 | 2-50 |
| **Common/ striped dolphin** | *D. delphinus/ S. coeruleoalba* | 1 | 1 | 1 |
| **Humpback whale** | *Megaptera novaeangliae* | 1 | 1 | 1 |
| **Long finned pilot whale** | *Globicephala melas* | 3 | 20 | 4-11 |
| **Minke whale** | *Balaenoptera acutorostrata* | 38 | 39 | 1-2 |
| **Mix (Bottlenose dolphin & pilot whale)** | *Mix (T. truncatus & G. melas)* | 1 | (20 & 20) | 40 |
| **Mix (Common dolphin & minke whale)** | *Mix (D. delphinus & B. acutorostrata)* | 1 | (100 & 2) | 102 |
| **Risso's dolphin** | *Grampus griseus* | 5 | 47 | 6-15 |
| **White beaked dolphin** | *Lagenorhynchus albirostris* | 4 | 10 | 2-3 |
| **Unid Baleen Whale** | *Mysticeti sp* | 4 | 4 | 1 |
| **Unid Cetacean** | *Cetacea sp* | 2 | 2 | 1 |
| **Unid Dolphin** | *Delphinid sp* | 20 | 192 | 1-70 |
| **Unid Large Whale** | | 2 | 2 | 1 |
| **Unid Small Whale** | | 1 | 1 | 1 |
| | **Total** | **160** | **950** | |
| | | | | |
| | | | | |
| **Grey Seal** | *Halichoerus grypus* | 3 | 4 | 1-2 |
| | Unidentified Seal | 2 | 2 | 1 |
| | **Total** | **5** | **6** | |
| | | | | |
| | | | | |
| **Decomposing Carcass** | Unid. marine mammal | 2 | 2 | 1 |
| | **Total** | **2** | **2** | |
| | | | | |
| | | | | |
| **Basking shark** | *Cetorhinus maximus* | 1 | 1 | 1 |
| **Blue shark** | *Prionace glauca* | 4 | 4 | 1 |
| **Leatherback turtle** | *Dermochelys coriacea* | 2 | 2 | 1 |
| **Ocean sunfish** | *Mola mola* | 25 | 25 | 1 |
| **Porbeagle shark** | *Lamna nasus* | 1 | 1 | 1 |
| **Tuna Sp** | *Thunnus sp* | 1 | 1 | 1 |
| **Unidentified Fish** | *Teleost sp* | 1 | 2 | 2 |
| **Unidentified Shark** | *Selachii sp* | 1 | 1 | 1 |
| | **Total** | **36** | **37** | |

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**Table 15.** Totals for all seabird species recorded between 10th June and 23rd July 2018.

Leg 1:

| Vernacular Name | Scientific Name | On Survey | Off Survey | Total |
|---|---|---|---|---|
| Wilson's storm-petrel | *Oceanites oceanicus* | 0 | 1 | 1 |
| European storm-petrel | *Hydrobates pelagicus* | 38 | 277 | 315 |
| Fulmar | *Fulmarus glacialis* | 61 | 356 | 417 |
| Sooty shearwater | *Ardenna griseus* | 1 | 4 | 5 |
| Great shearwater | *Ardenna gravis* | 3 | 1 | 4 |
| Manx shearwater | *Puffinus puffinus* | 89 | 92 | 181 |
| Gannet | *Morus bassanus* | 248 | 2334 | 2582 |
| Kittiwake | *Rissa tridactyla* | 5 | 10 | 15 |
| Sabine's gull | *Xema sabini* | 2 | 0 | 2 |
| Great black-backed gull | *Larus marinus* | 4 | 23 | 27 |
| Herring gull | *Larus argentatus* | 0 | 21 | 21 |
| Lesser black-backed gull | *Larus fuscus graellsii* | 176 | 446 | 622 |
| Unidentified gull sp. | *Larus sp.* | 0 | 2 | 2 |
| Common tern | *Sterna hirundo* | 0 | 6 | 6 |
| Great skua | *Stercorarius skua* | 4 | 19 | 23 |
| Arctic Skua | *Stercorarius parasiticus* | 0 | 1 | 1 |
| Guillemot | *Uria aalge* | 38 | 9 | 47 |
| Razorbill | *Alca torda* | 5 | 1 | 6 |
| Puffin | *Fratercula arctica* | 98 | 59 | 157 |
| **Total** | | 772 | 3662 | 4434 |

Leg 2:

| Vernacular Name | Scientific Name | On Survey | Off Survey | Total |
|---|---|---|---|---|
| Great Northern Diver | Gavia immer | 1 | 0 | 1 |
| European storm-petrel | *Hydrobates pelagicus* | 22 | 19 | 41 |
| Unidentified storm-petrel | | 1 | 6 | 7 |
| Fulmar | *Fulmarus glacialis* | 275 | 667 | 942 |
| Cory's shearwater | *Calonectris borealis* | 4 | 2 | 6 |
| Sooty shearwater | *Ardenna griseus* | 2 | 6 | 8 |
| Great shearwater | *Ardenna gravis* | 0 | 2 | 2 |
| Manx shearwater | *Puffinus puffinus* | 285 | 302 | 587 |
| Unidentified shearwater sp. | | 1 | 0 | 1 |
| Gannet | *Morus bassanus* | 784 | 1208 | 1992 |
| Shag | *Phalacrocorax aristotelis* | 0 | 5 | 5 |
| Cormorant | *Phalacrocorax carbo* | 0 | 4 | 4 |
| Kittiwake | *Rissa tridactyla* | 25 | 44 | 69 |
| Common gull | *Larus canus* | 2 | 10 | 12 |
| Great black-backed gull | *Larus marinus* | 2 | 12 | 14 |
| Herring gull | *Larus argentatus* | 2 | 11 | 13 |
| Lesser black-backed gull | *Larus fuscus graellsii* | 62 | 141 | 203 |
| Unidentified large gull sp. | *Larus sp.* | 21 | 4 | 25 |
| Common tern | *Sterna hirundo* | 0 | 1 | 1 |
| Arctic tern | *Sterna paradisaea* | 0 | 3 | 3 |
| Unidentified *Sterna* tern sp. | *Sterna sp.* | 0 | 17 | 17 |
| Great skua | *Stercorarius skua* | 17 | 24 | 41 |
| Pomarine skua | *Stercorarius pomarinus* | 0 | 1 | 1 |
| Arctic skua | *Stercorarius parasiticus* | 1 | 1 | 2 |
| Guillemot | *Uria aalge* | 393 | 243 | 636 |
| Razorbill | *Alca torda* | 227 | 88 | 315 |
| Unidentified Guillemot/Razorbill | | 552 | 651 | 1203 |
| Puffin | *Fratercula arctica* | 219 | 346 | 565 |
| Black Guillemot | *Cepphus grylle* | 0 | 1 | 1 |
| **Total** | | 2898 | 3819 | 6717 |

**Table 16.** Totals of migrant terrestrial bird species recorded between 10th June and 23rd July 2018.

Leg 1:

| Vernacular Name | Scientific Name | Total |
|---|---|---|
| Unidentified passerine sp. | | 1 |
| Racing pigeon | *Columba livia* domest. | 7 |
| Swift | *Apus apus* | 1 |
| Collared dove | *Streptopelia dedaocto* | 6 |
| **Total** | | 15 |

Leg 2:

| Vernacular Name | Scientific Name | Total |
|---|---|---|
| Dunlin | *Calidris alpina* | 25 |
| **Total** | | 25 |

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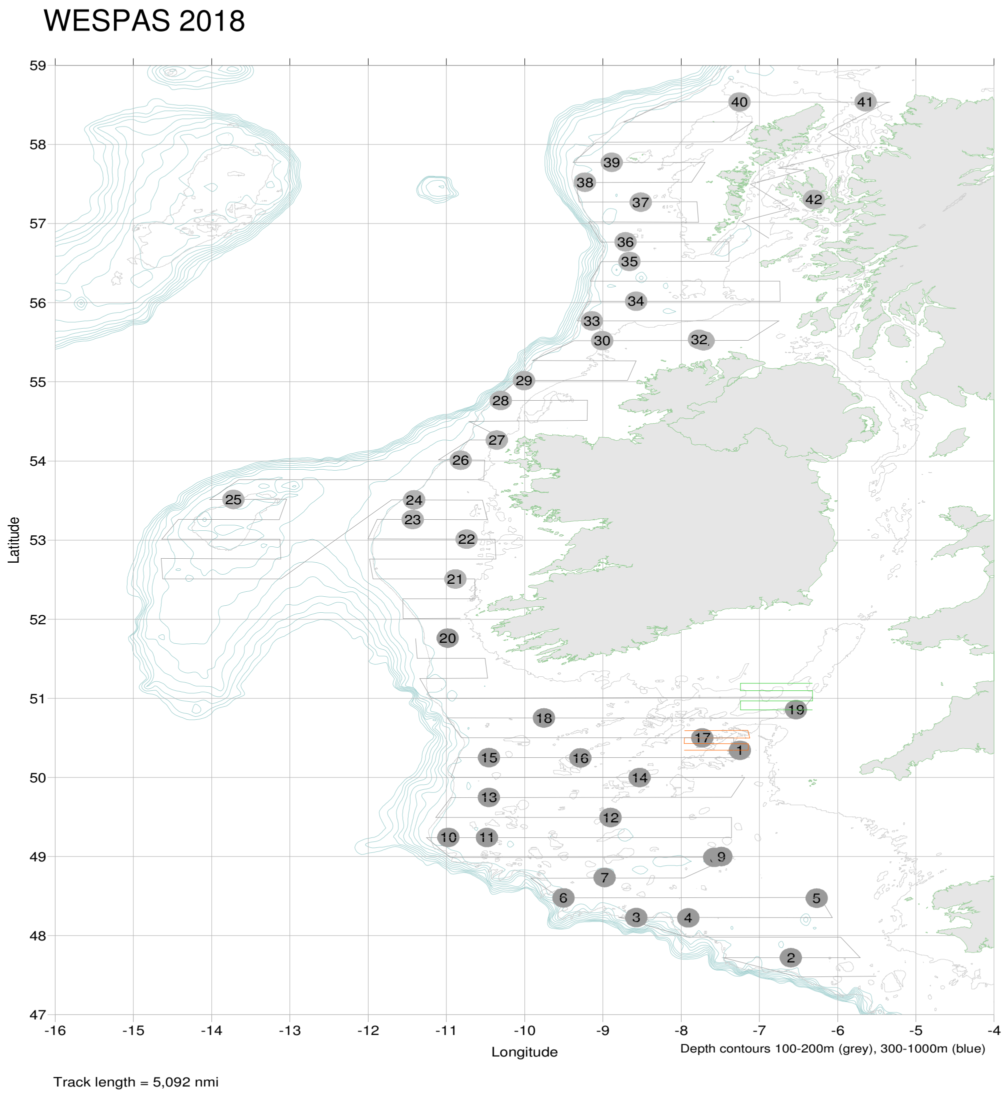


**Figure 1.** Survey cruise track (grey line) and numbered directed pelagic trawl stations. Corresponding catch details are provided in Table 2. Green line indicates transect survey conducted by autonomous vehicle in the western Celtic Deep and orange line indicates survey carried out by the *C. Explorer* on the Northwest bank.

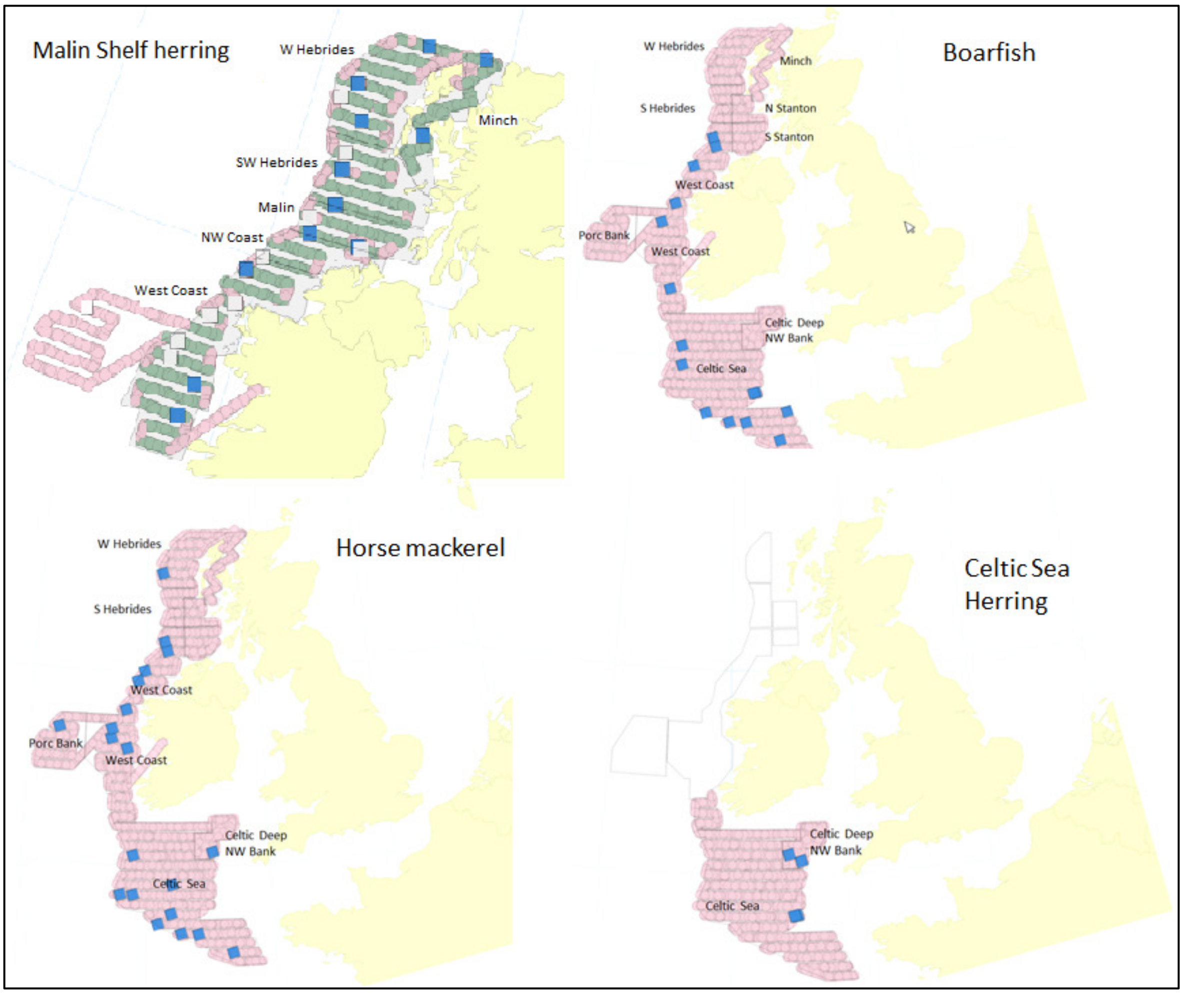


**Figure 2.** Acoustic sampling area stratification as applied during the calculation of species specific acoustic abundance.

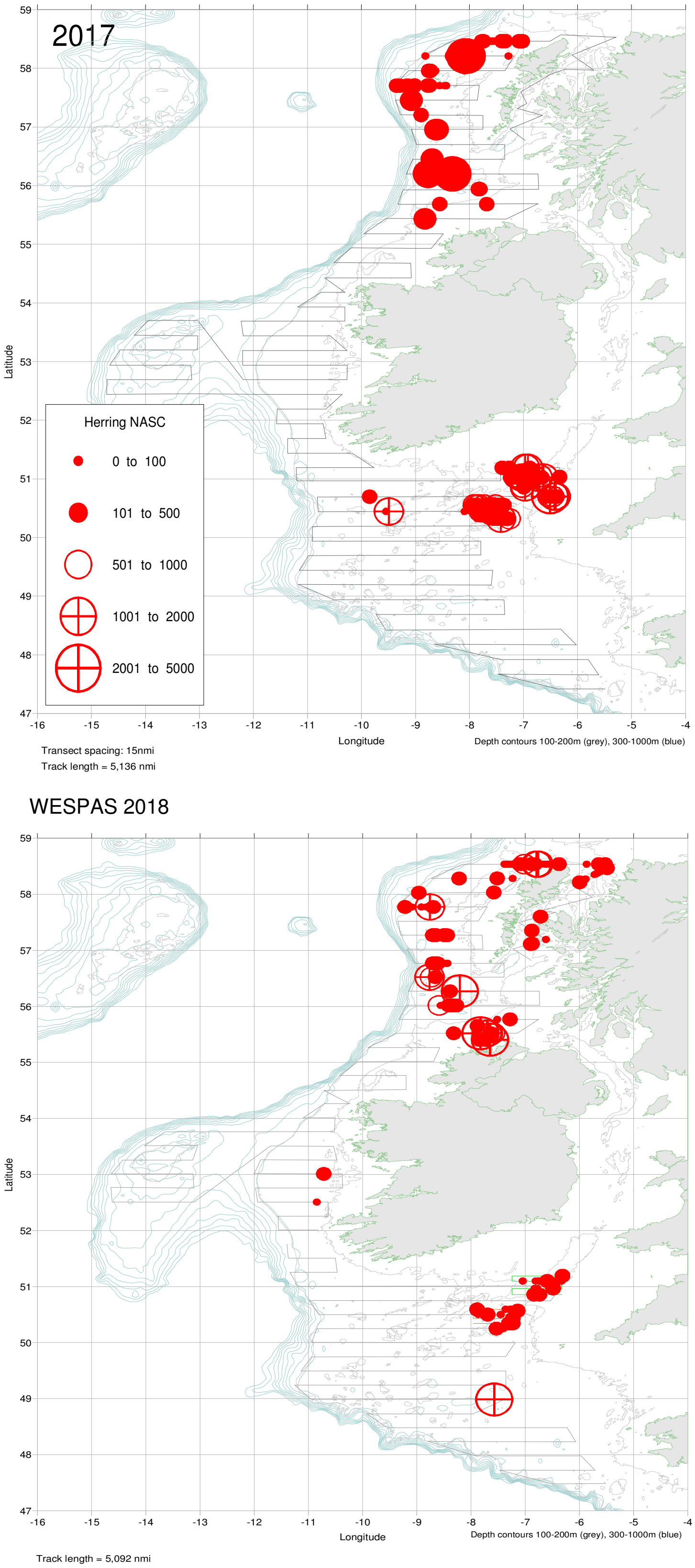


**Figure 3.** Malin Shelf (north of 54°N) and Celtic Sea (south of 52°N) herring distribution by weighted acoustic density and Celtic Sea her. Top panel 2017, bottom panel 2018.

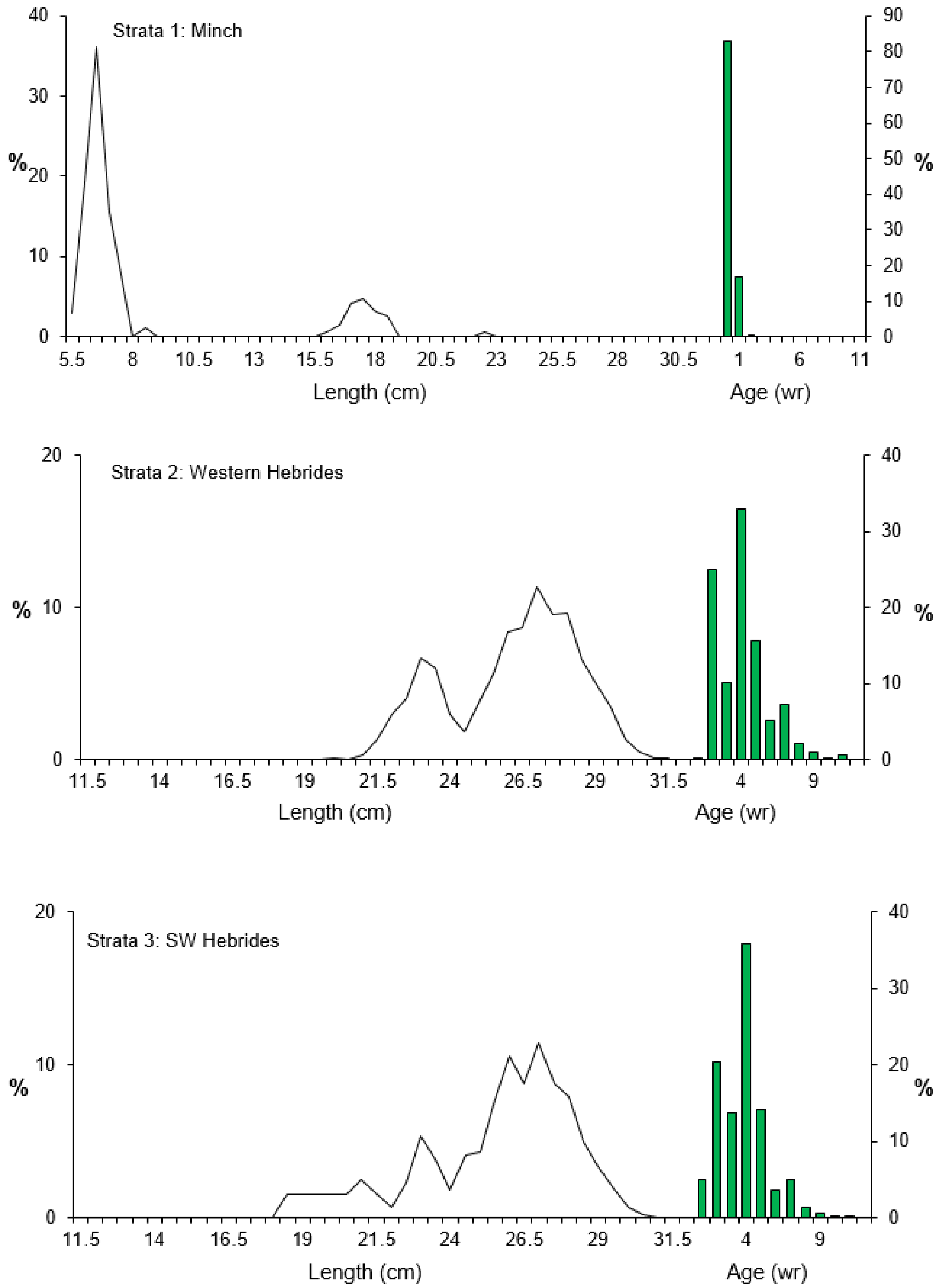


**Figure 4.** Length and age distribution of Malin Shelf herring by stratum and total survey area during WESPAS 2018.

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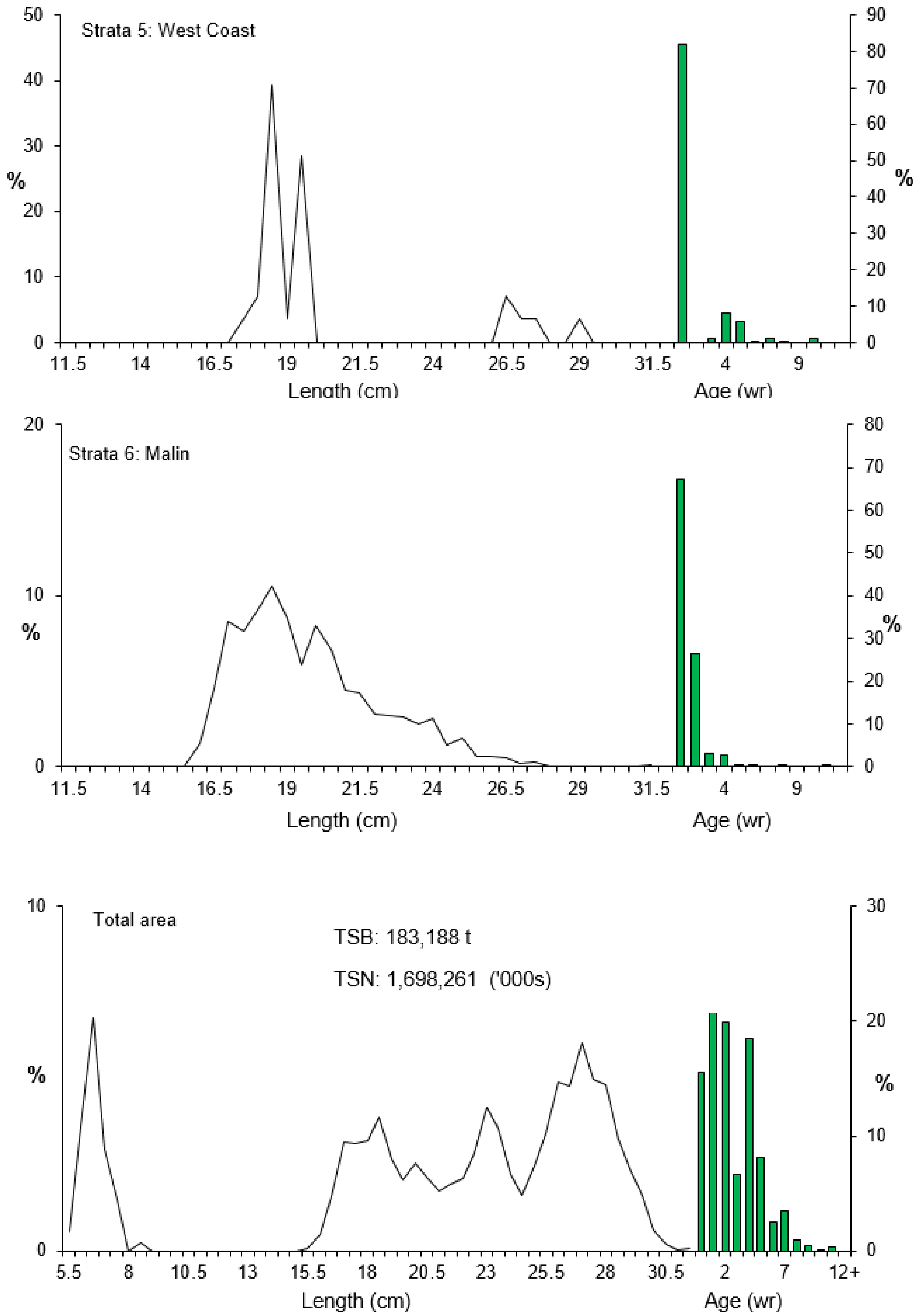


**Figure 4.** Cont.

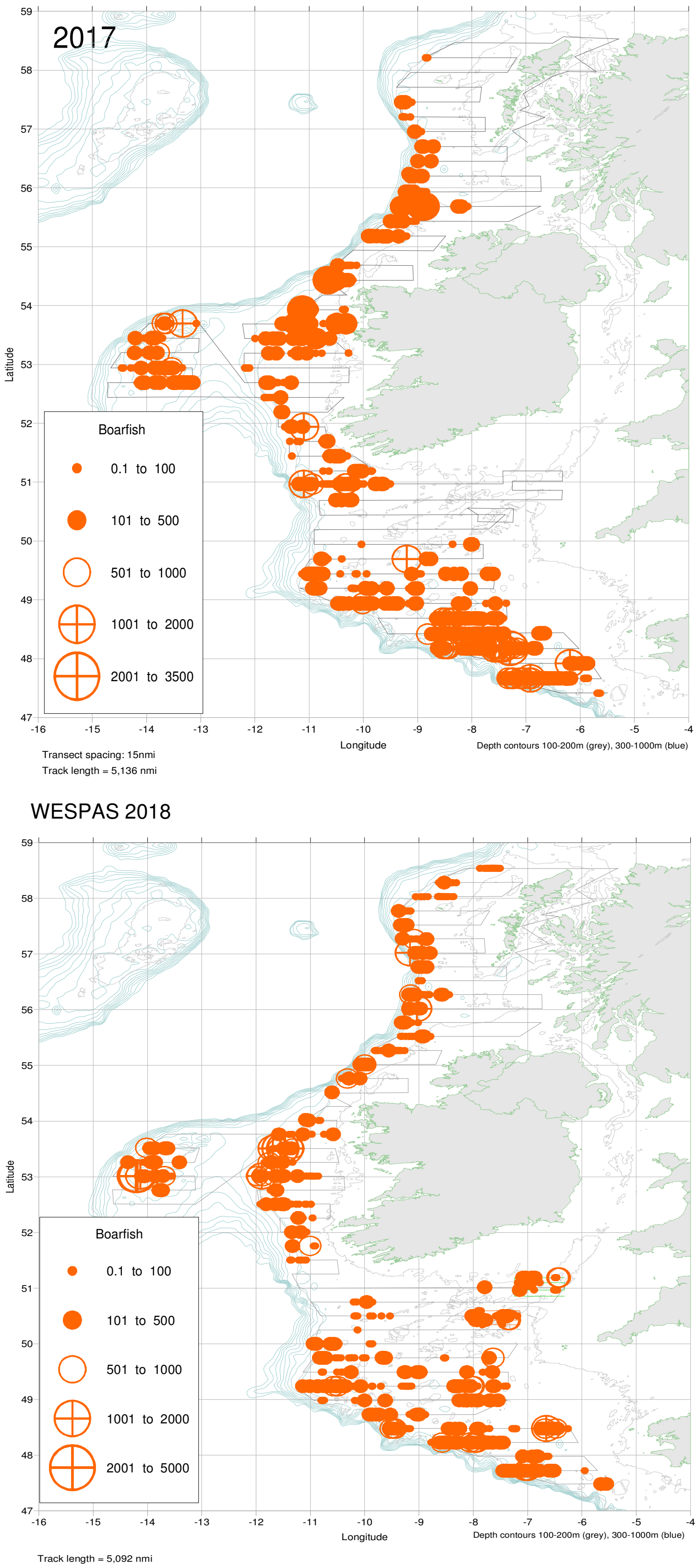


**Figure 5.** Boarfish distribution by weighted acoustic density. Top panel 2017, bottom panel 2018.

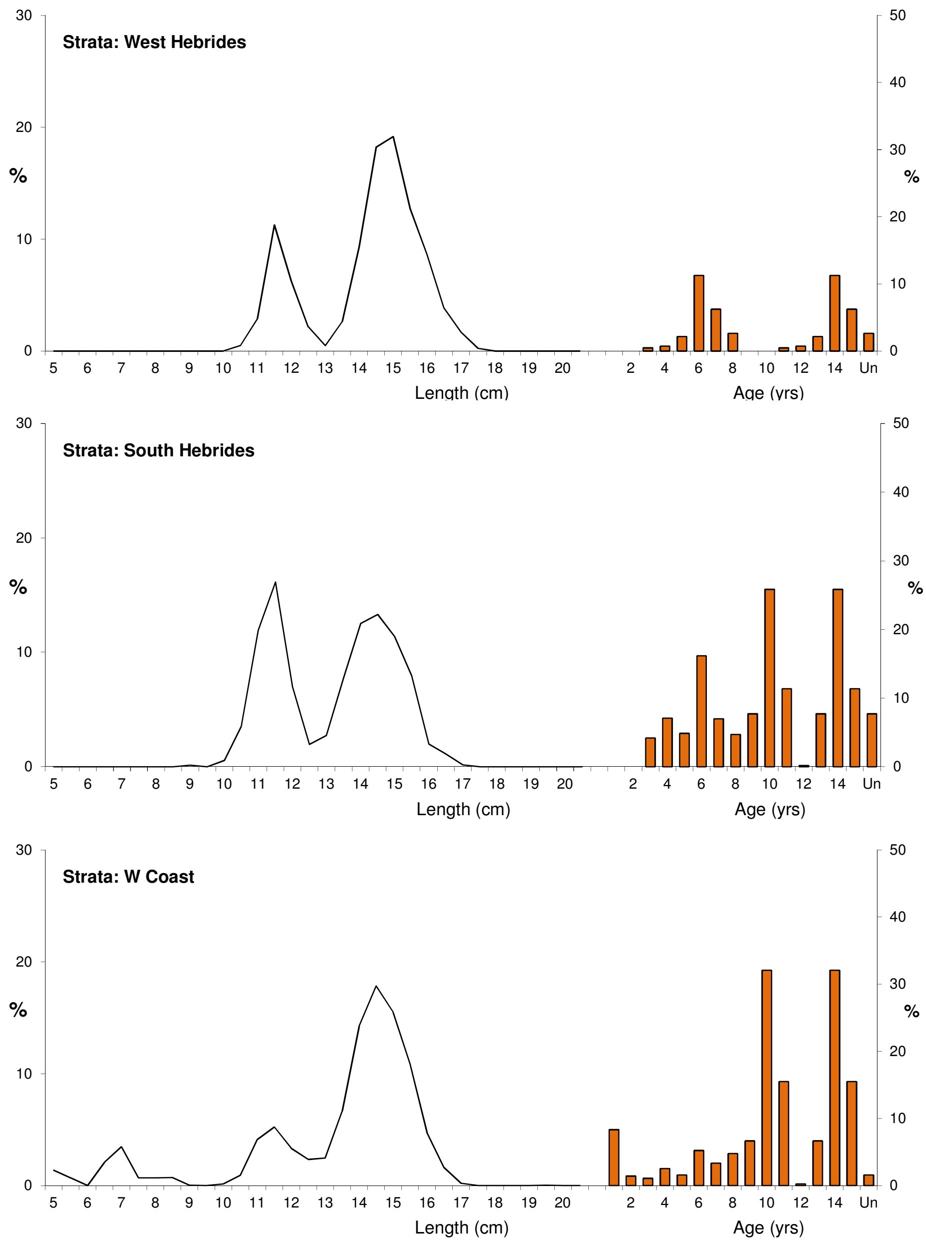


**Figure 6.** Length and age distribution of boarfish by stratum and total survey area.

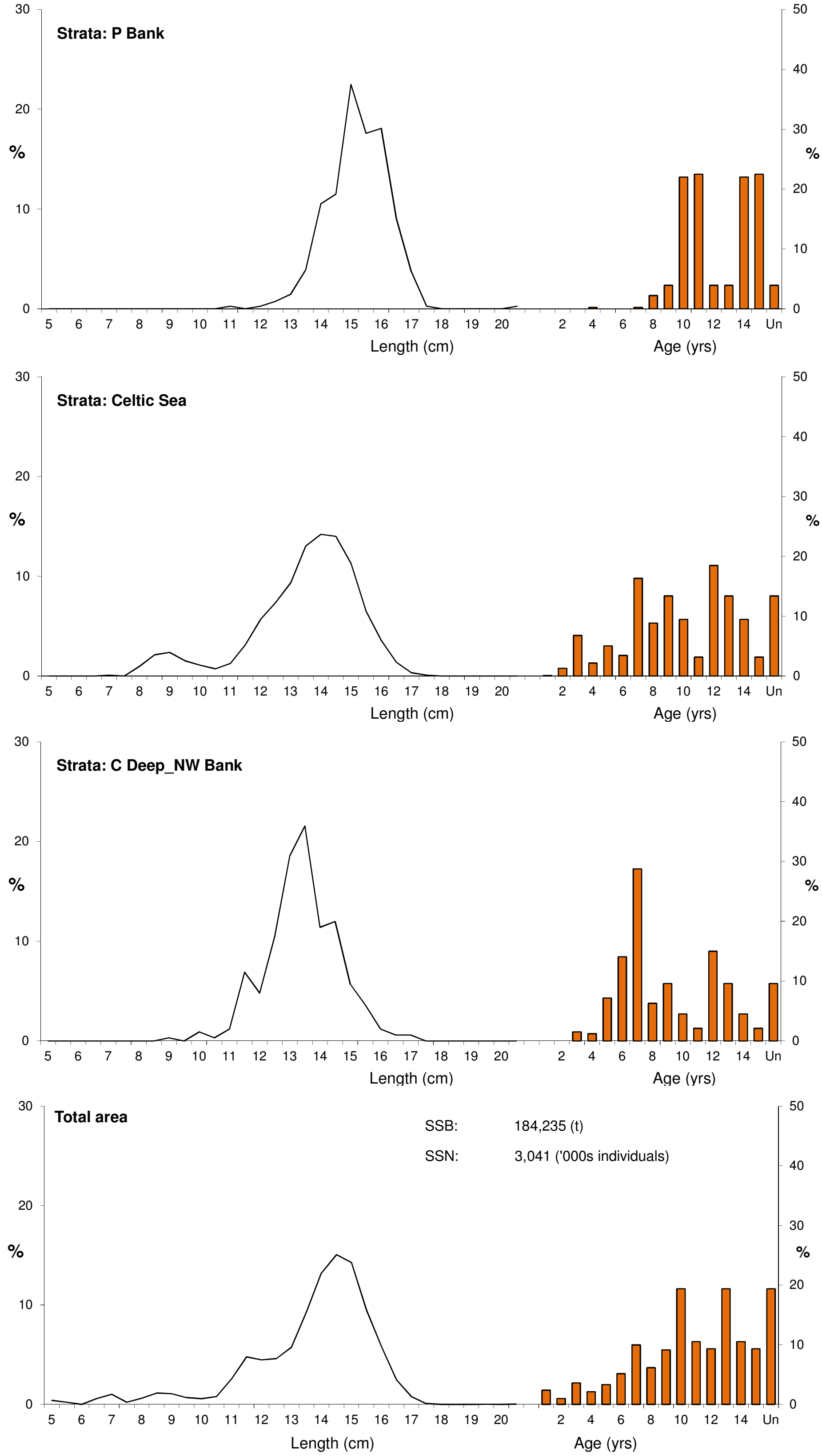


**Figure 6.** cont.

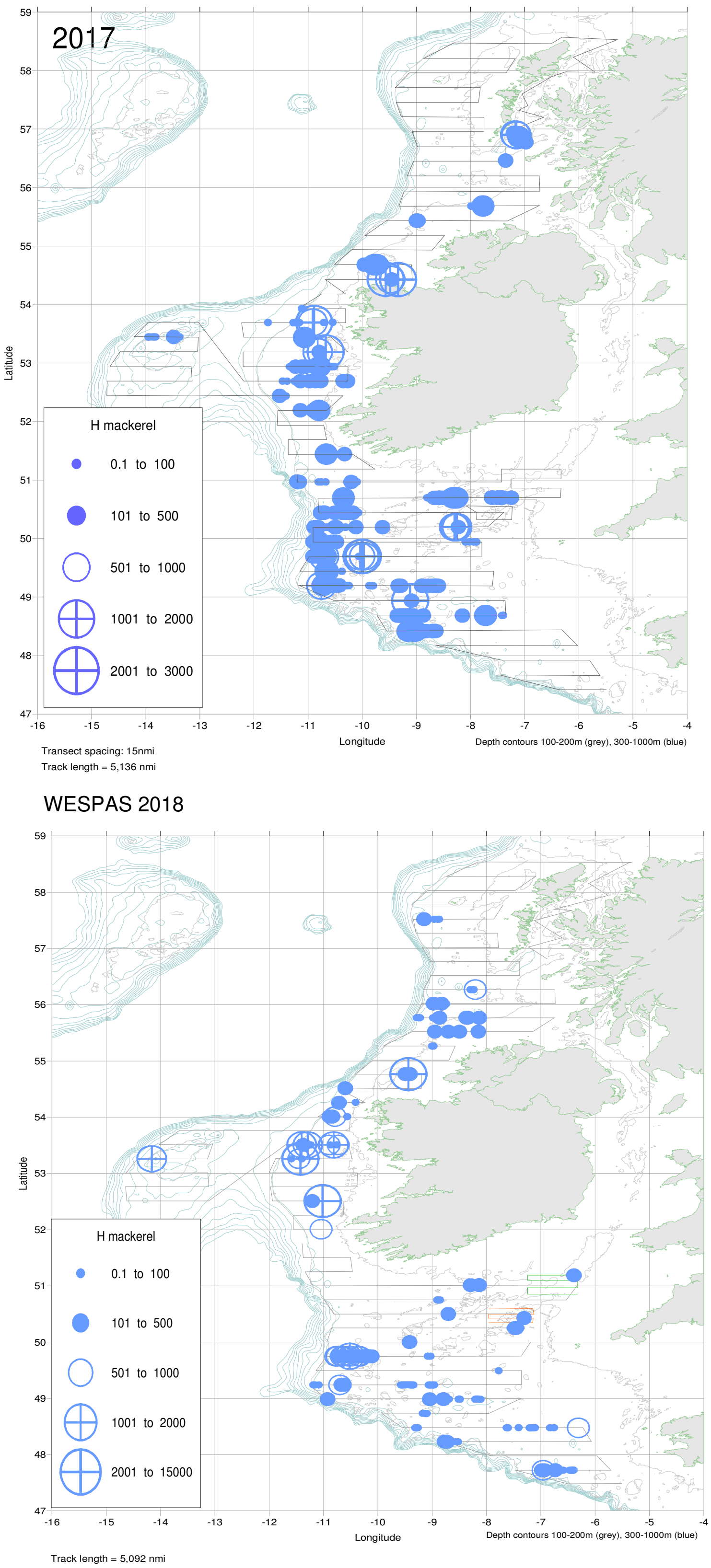


**Figure 7.** Horse mackerel distribution by weighted acoustic density. Top panel 2017, bottom panel 2018.

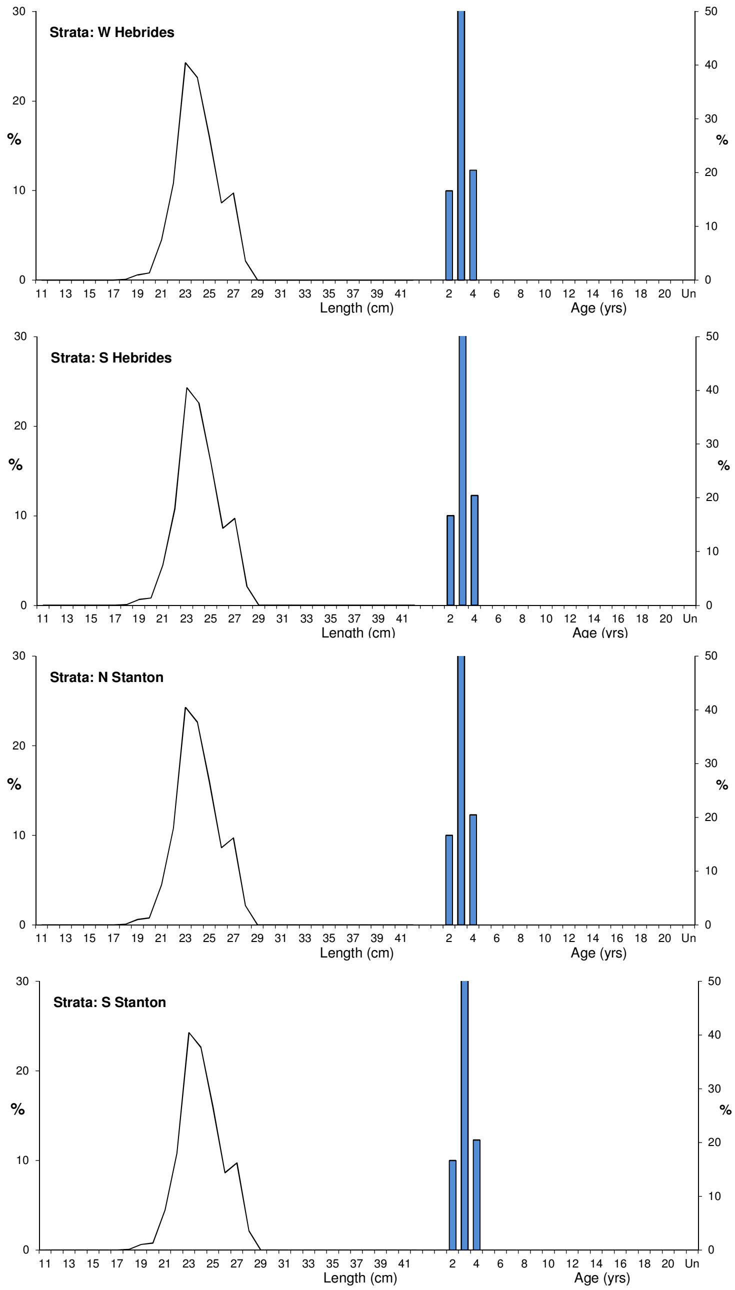


**Figure 8.** Length and age distribution of horse mackerel by stratum and total survey area.

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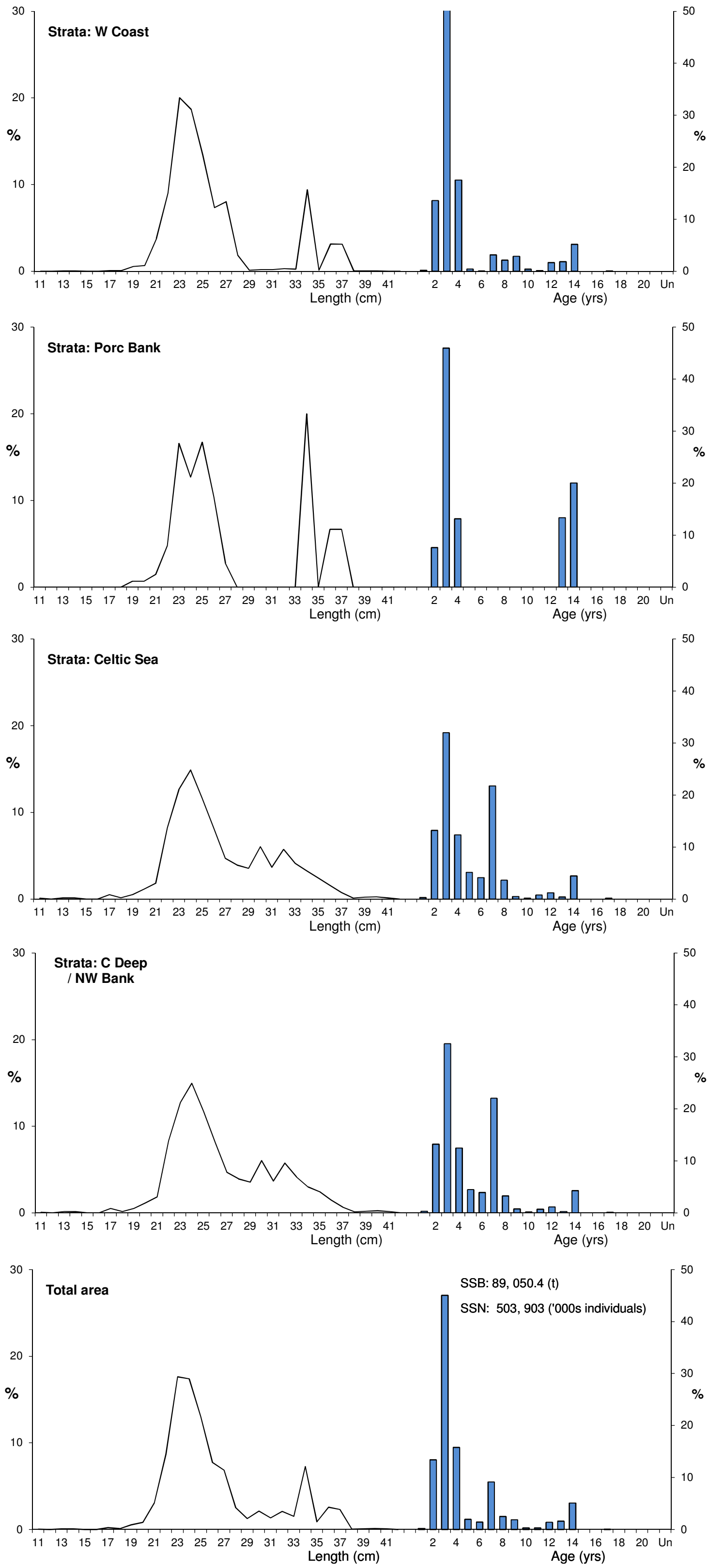


**Figure 8.** continue

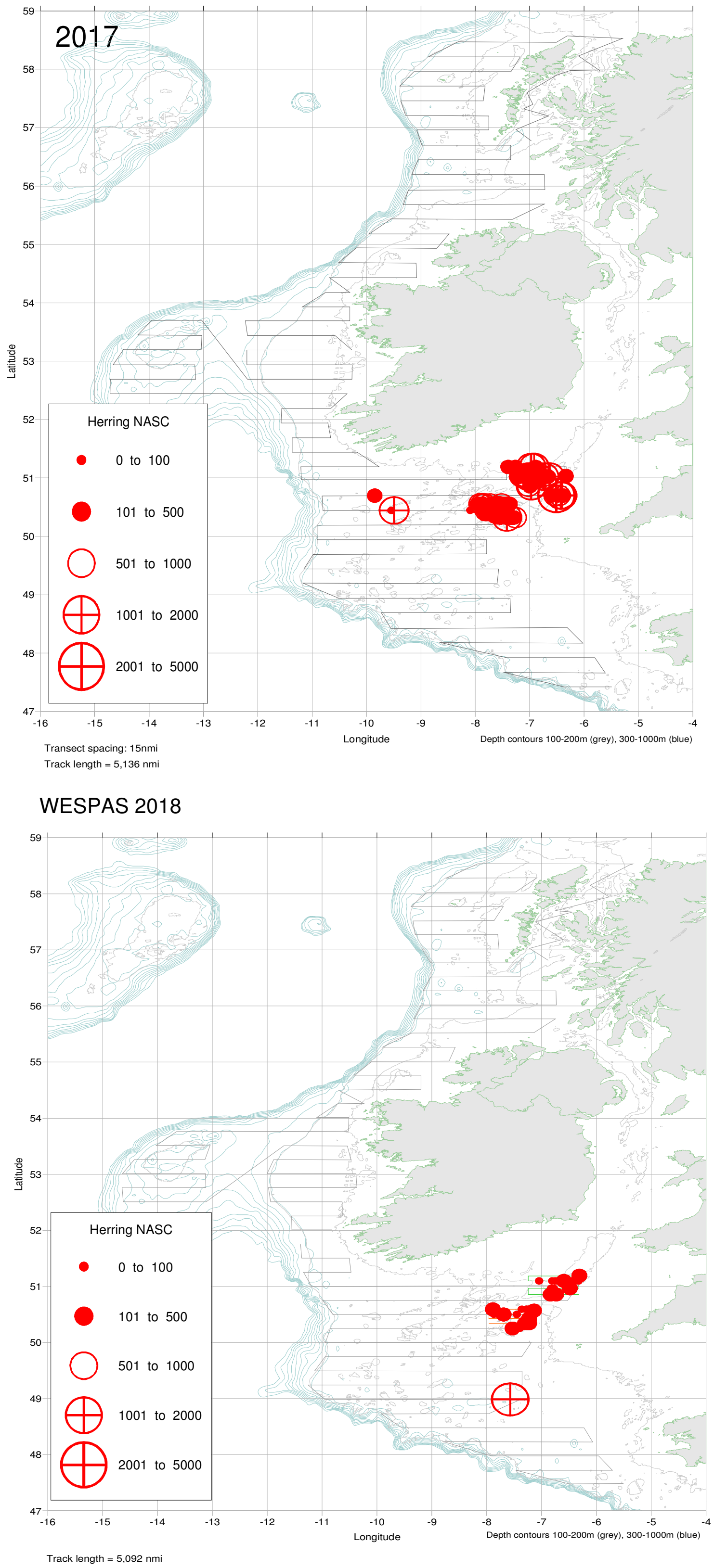


**Figure 9.** Celtic Sea herring distribution by NASC (Nautical area scattering coefficient)

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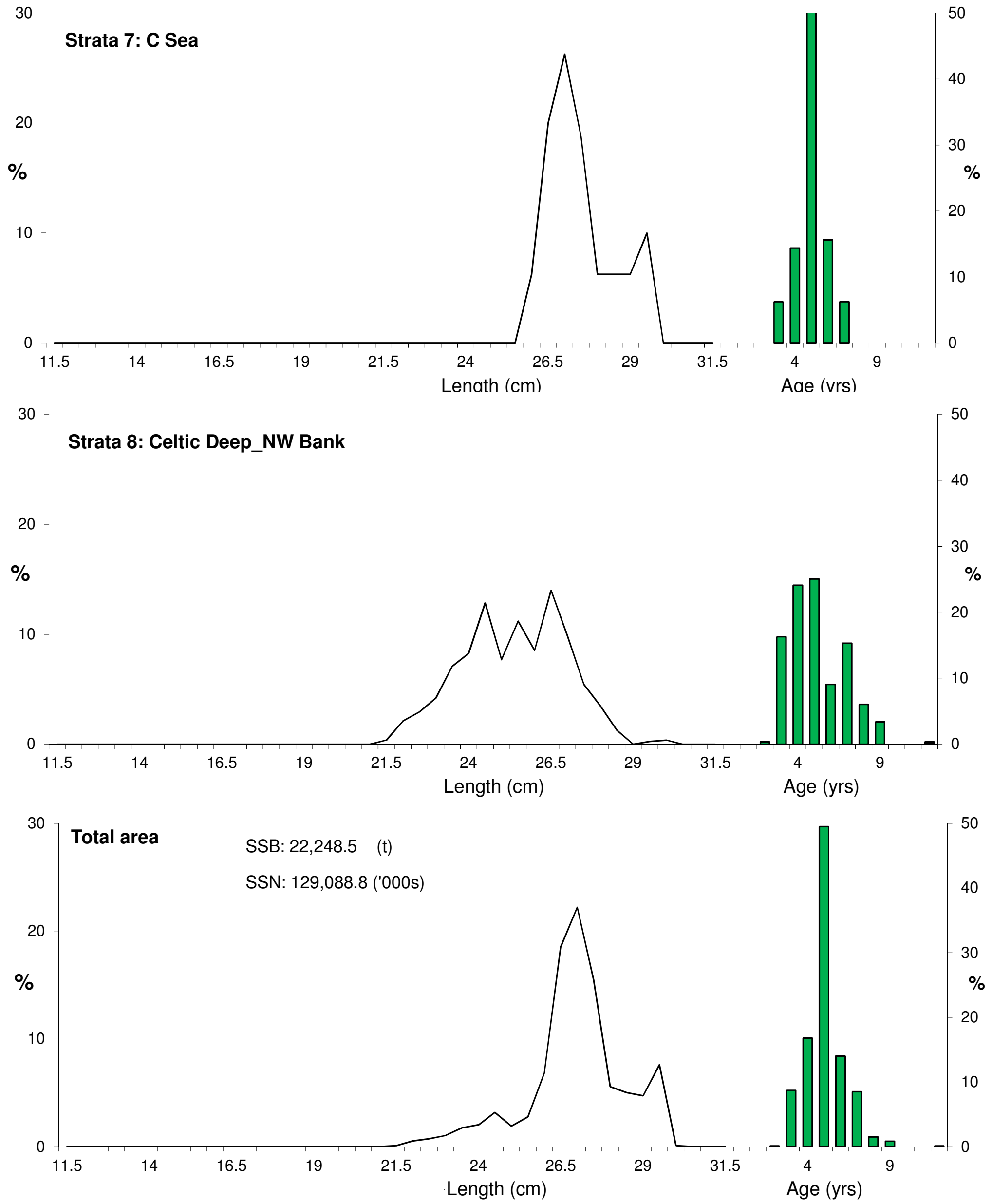
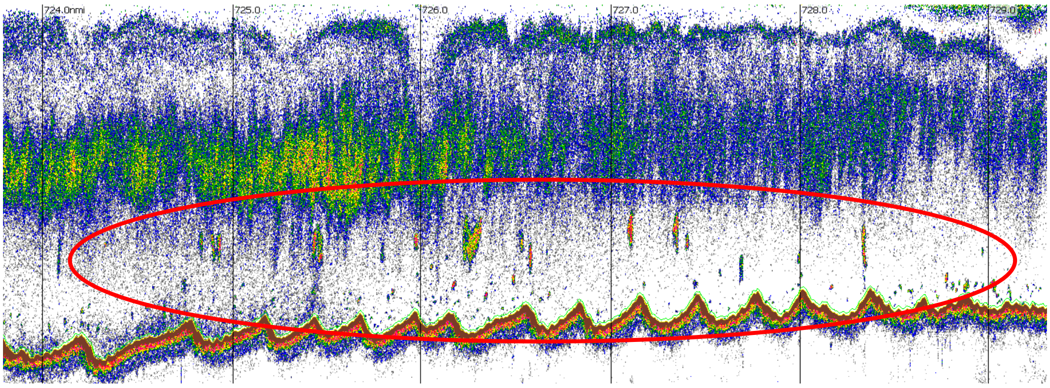
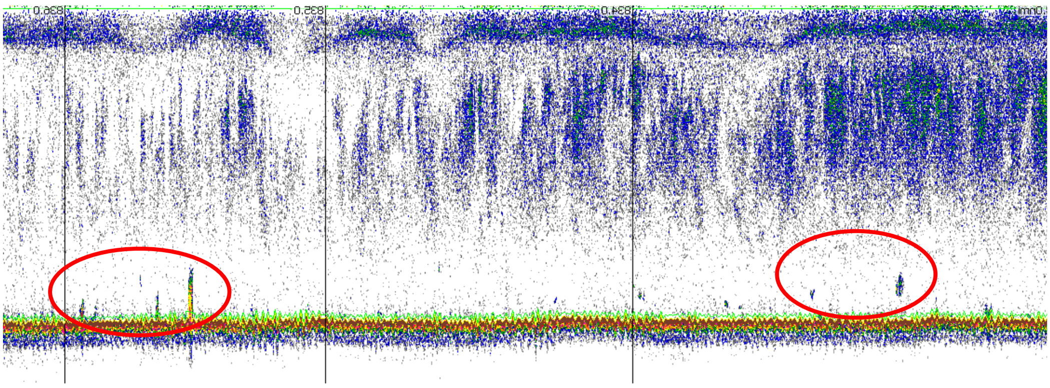


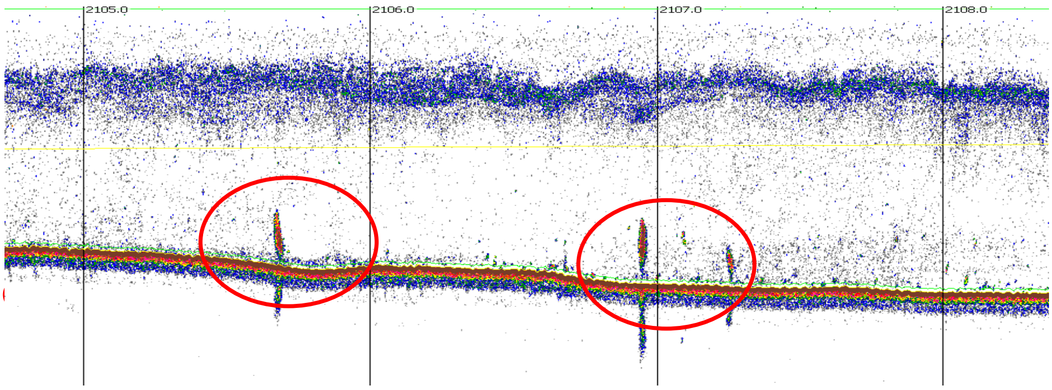

**Figure 10.** Length and age distribution of Celtic Sea herring by stratum and total survey area.




**a).** *Haul 04, Southern Celtic Sea. Pelagic schools of mature boarfish (circled red) close to the shelf edge. Water depth 180 m.*

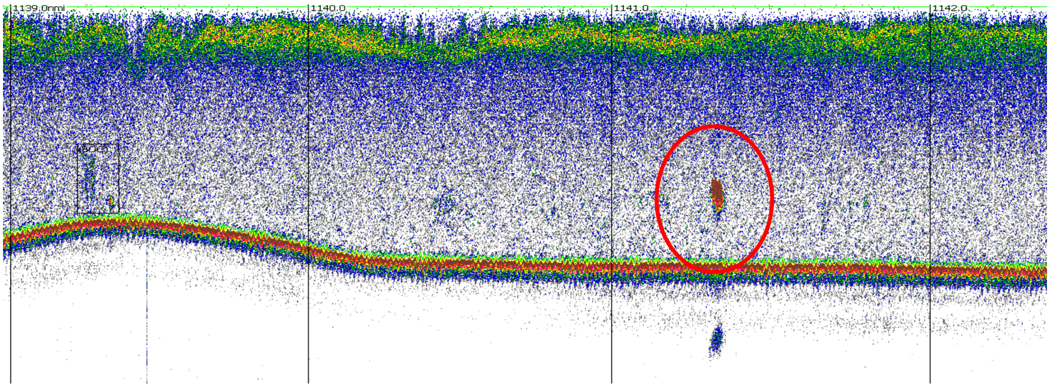


**b).** *Haul 05, Southern Celtic Sea. Medium density horse mackerel schools in the eastern survey area off the French coast. Water depth 130 m.*

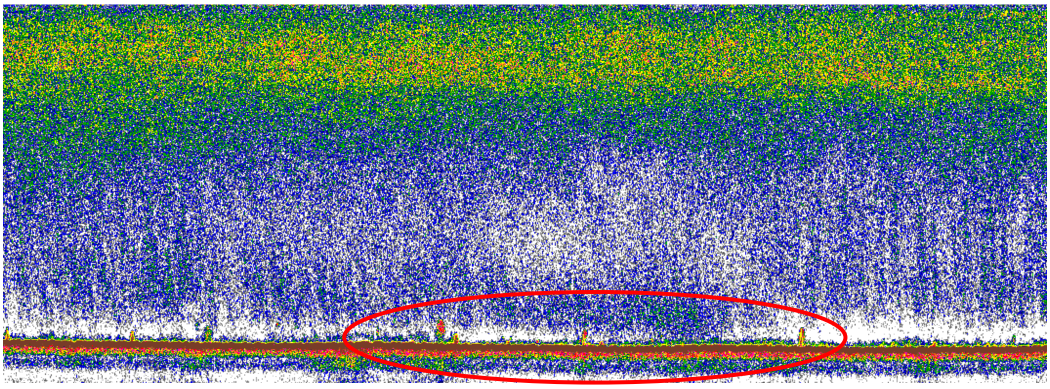



**c).** *Haul 16. Mid Celtic Sea. Example of high density schools of juvenile (0-group) blue whiting commonly encountered in the mid Celtic Sea. Water depth 132 m.*

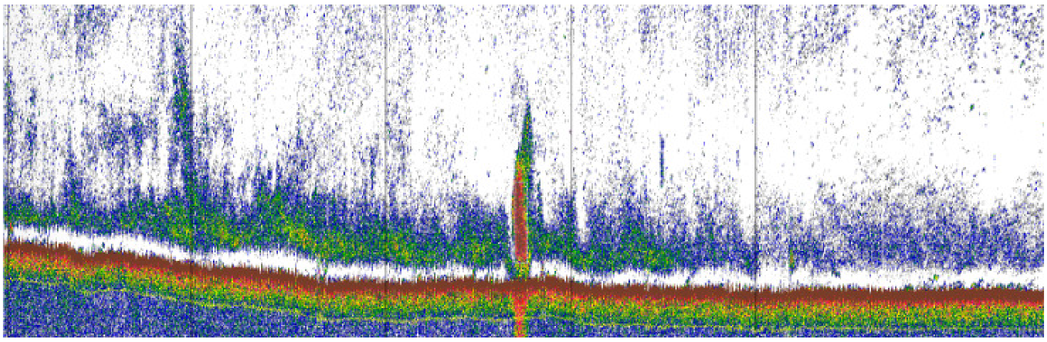
**Figures 11a-j.** Echotraces recorded on an EK60 echosounder (38 kHz) with images captured from Echoview. Note: Vertical bands on echogram represent 1nmi (nautical mile) intervals.




**d).** *Haul 08. High density single herring school located close to Jones Bank, water depth 146 m.*

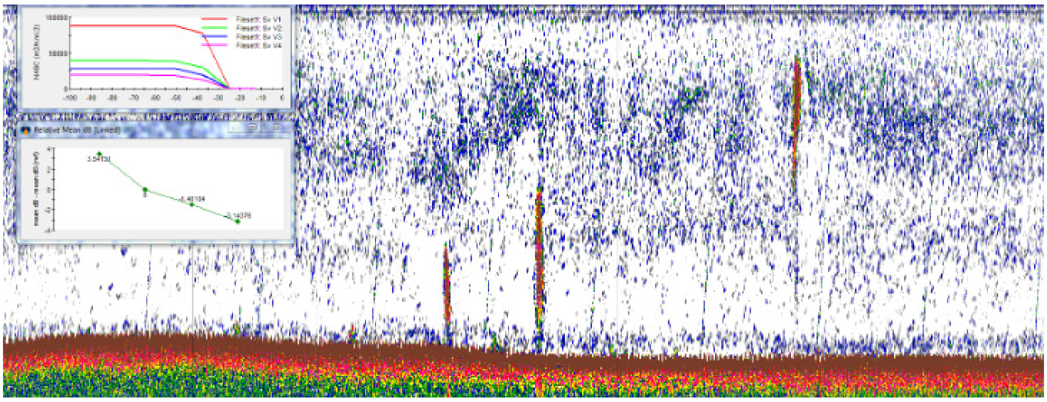


**e).** *Haul 01. Northwest Bank. Small, medium density schools of herring located on the bottom. Water depth 104 m.*

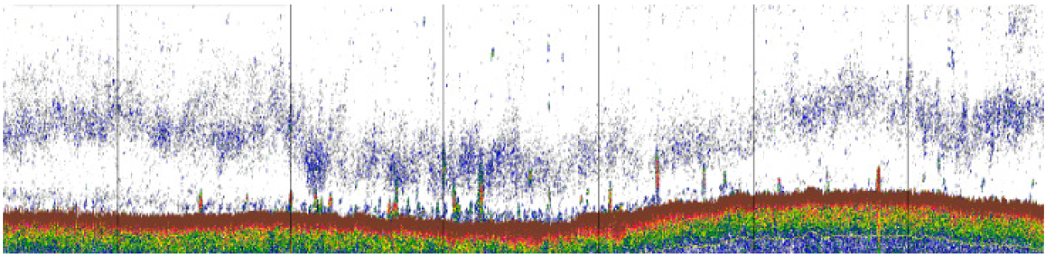


**f).** *Haul 39. SW of St. Kilda, high density herring school, water depth 152 m.*

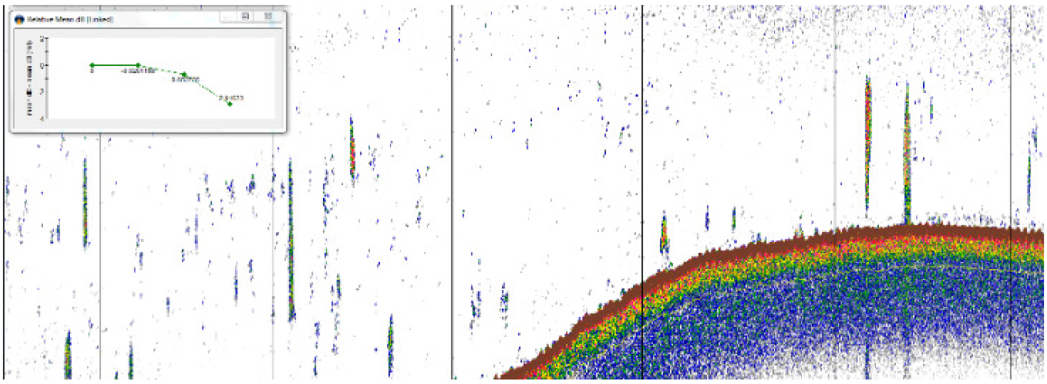
**Figures 11a-i.** continued



***g).*** *Haul 32. SE Stanton Bank, mid-water herring schools (mainly 1- and 2-wr) depth 69 m.*

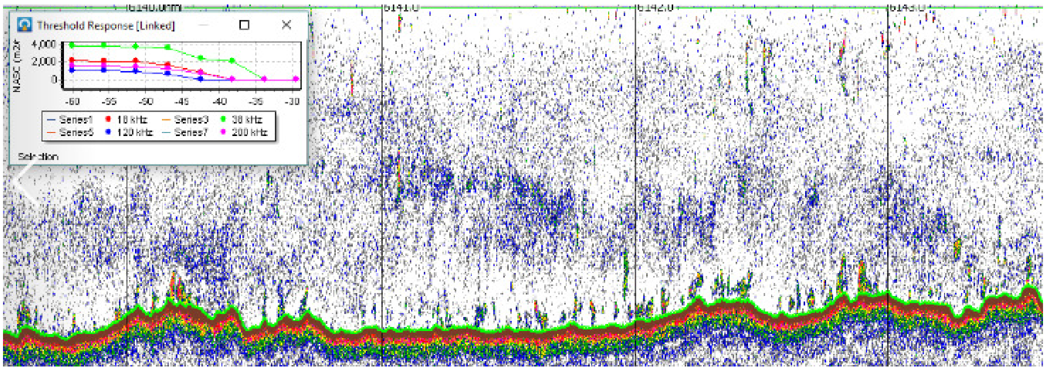


**h).** *Haul 35. W Stanton Bank, herring marks along bottom on hard ground, water depth 140 m.*

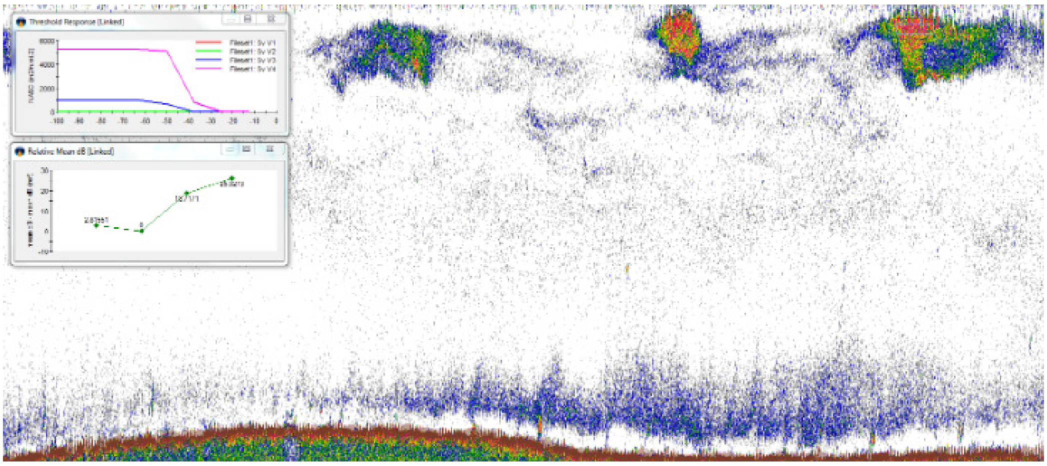


**i).** *Haul 29. West of Aranmore. High density marks of boarfish close to the shelf edge. Water depth 115-200 m.*

**Figures11-i.** continued.




**J).** *Surface marks of 0-group sprat and herring (with mixed gadoids on the bottom) in the Minch*




**k).** *Surface marks of mackerel as observed on the 200 kHz west of the Hebrides; common throughout the Malin Shelf area.*

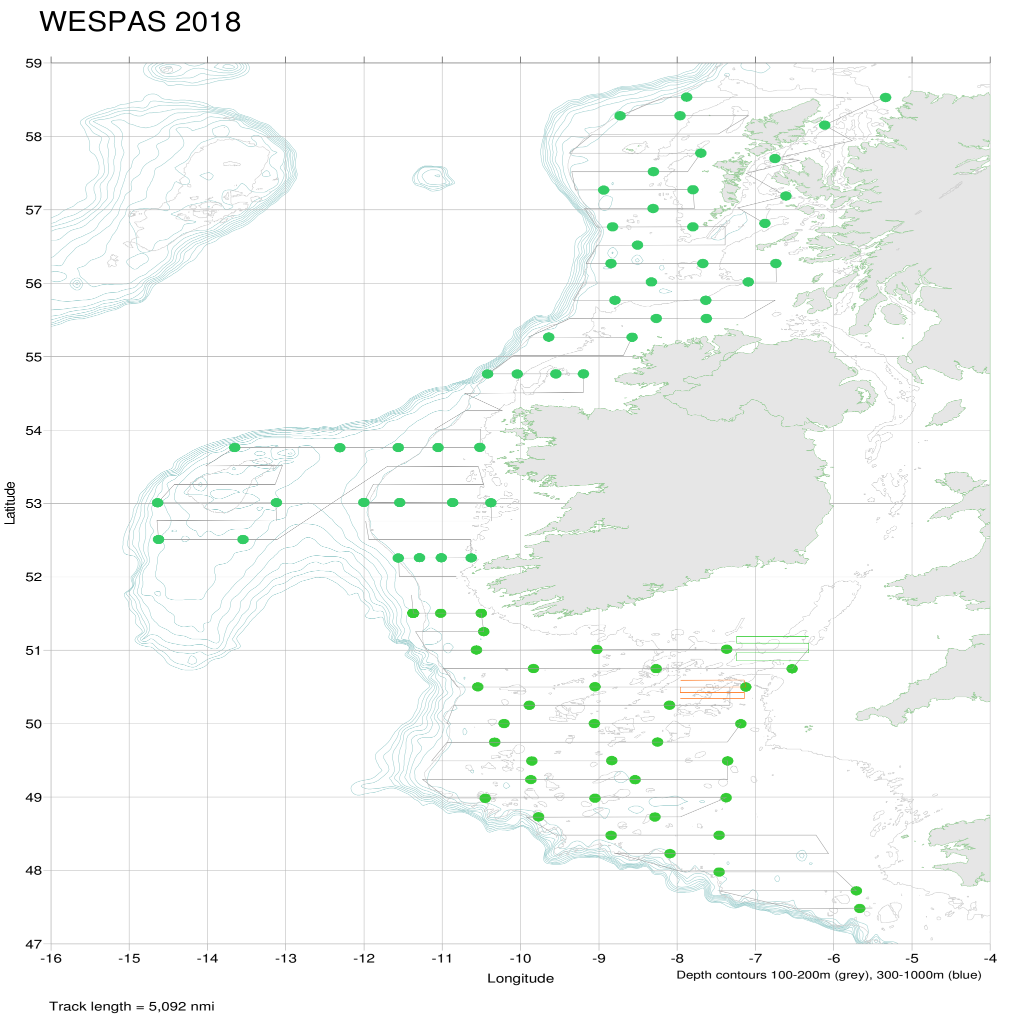



**Figure 12.** Position of hydrographic and co-occurring zooplankton sampling stations (n=86).

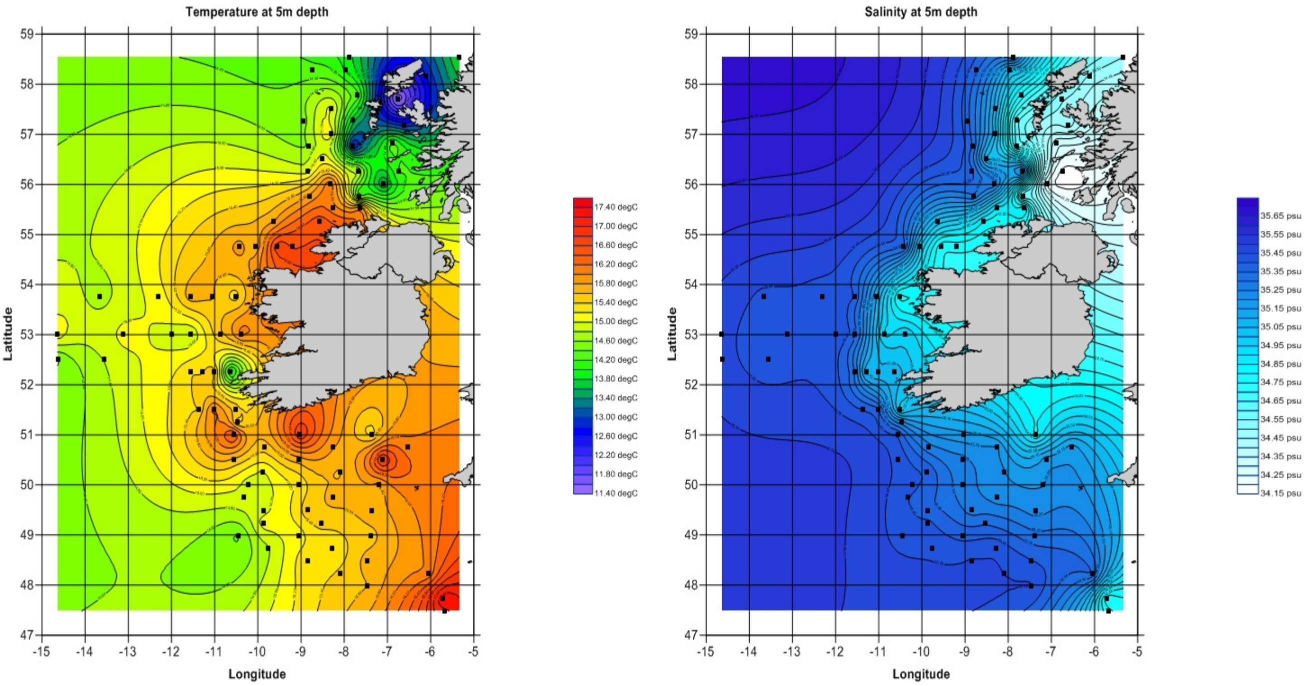



**Figure 13.** Surface (5m) plots of temperature and salinity compiled from CTD cast data. Station positions with valid data shown as block dots (n=86).

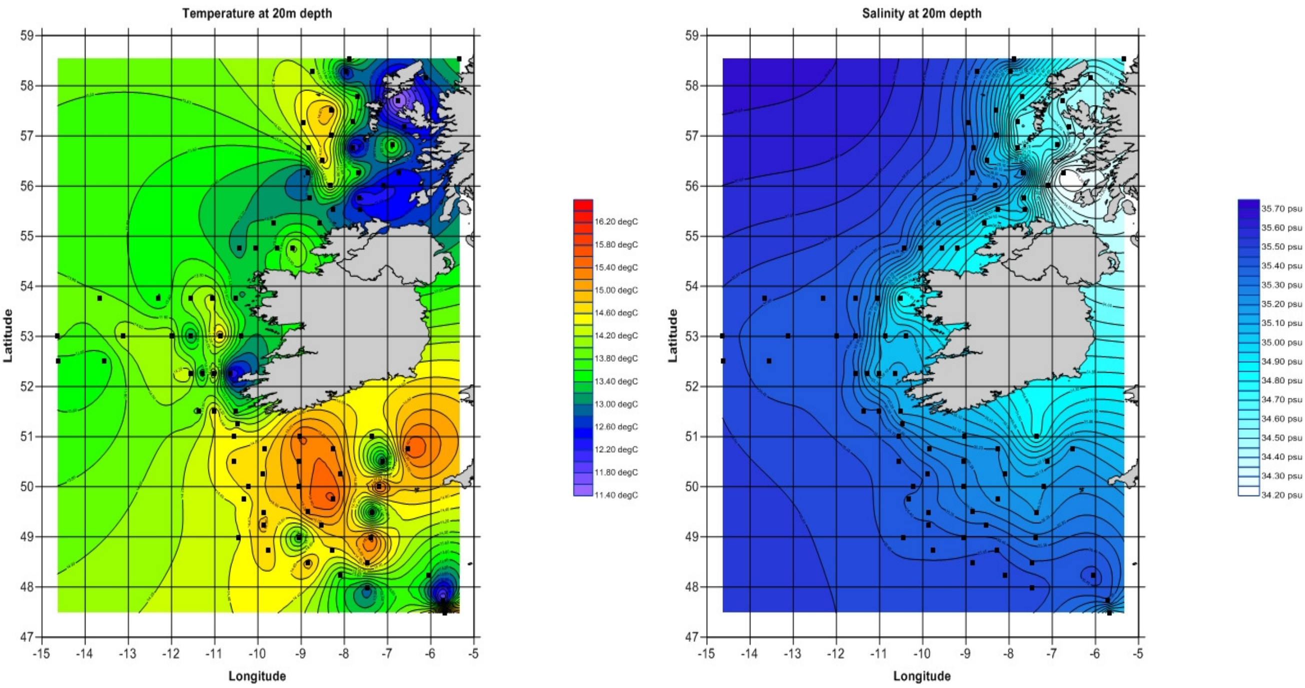



**Figure 14.** Plots of temperature and salinity compiled from CTD cast data at 20m depth. Station positions with valid data shown as block dots (n=86).

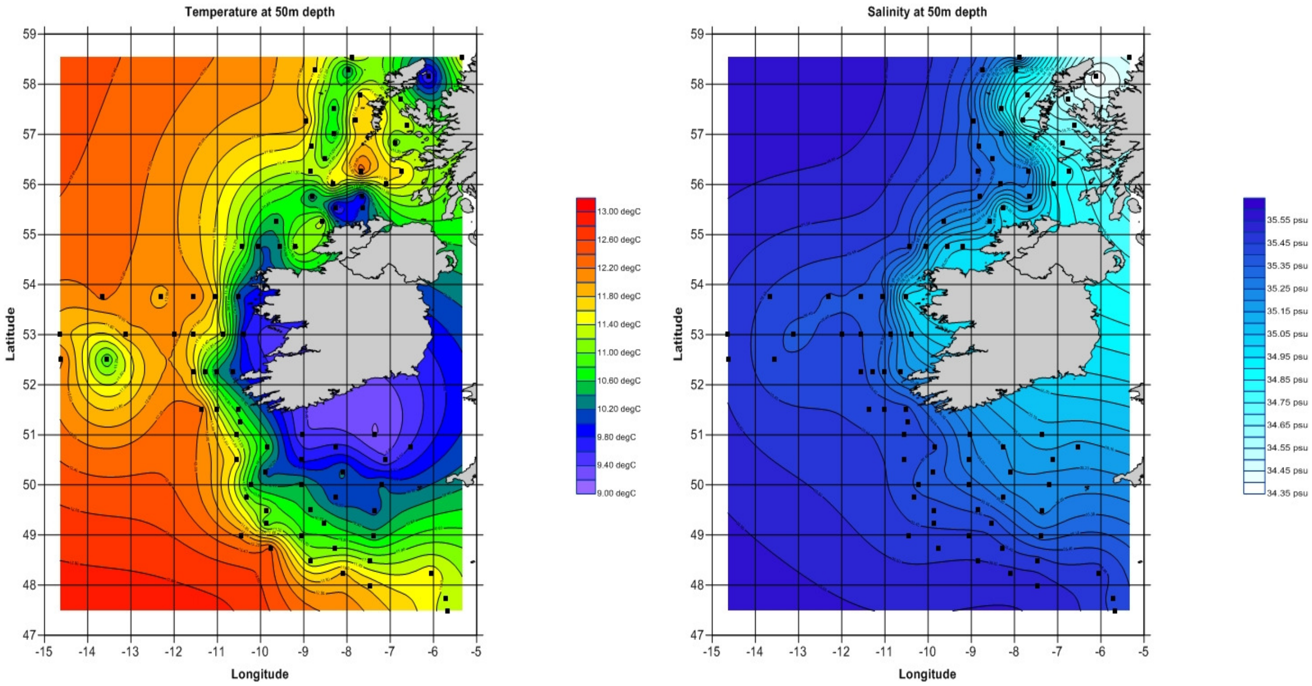



**Figure 15.** Plots of temperature and salinity compiled from CTD cast data at 50m depth. Station positions with valid data shown as block dots (n=86).

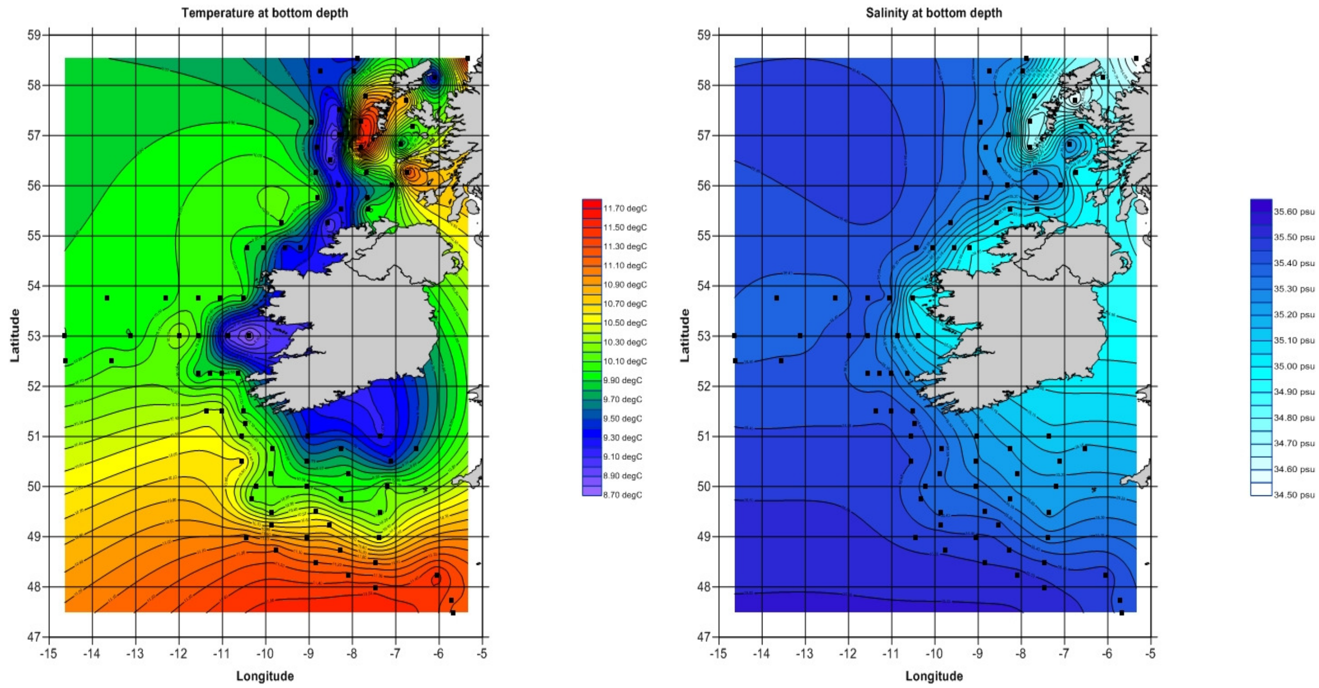



**Figure 16.** Plots of temperature and salinity compiled from CTD cast data at the seabed (+3-5m). Station positions with valid data shown as block dots (n=86).

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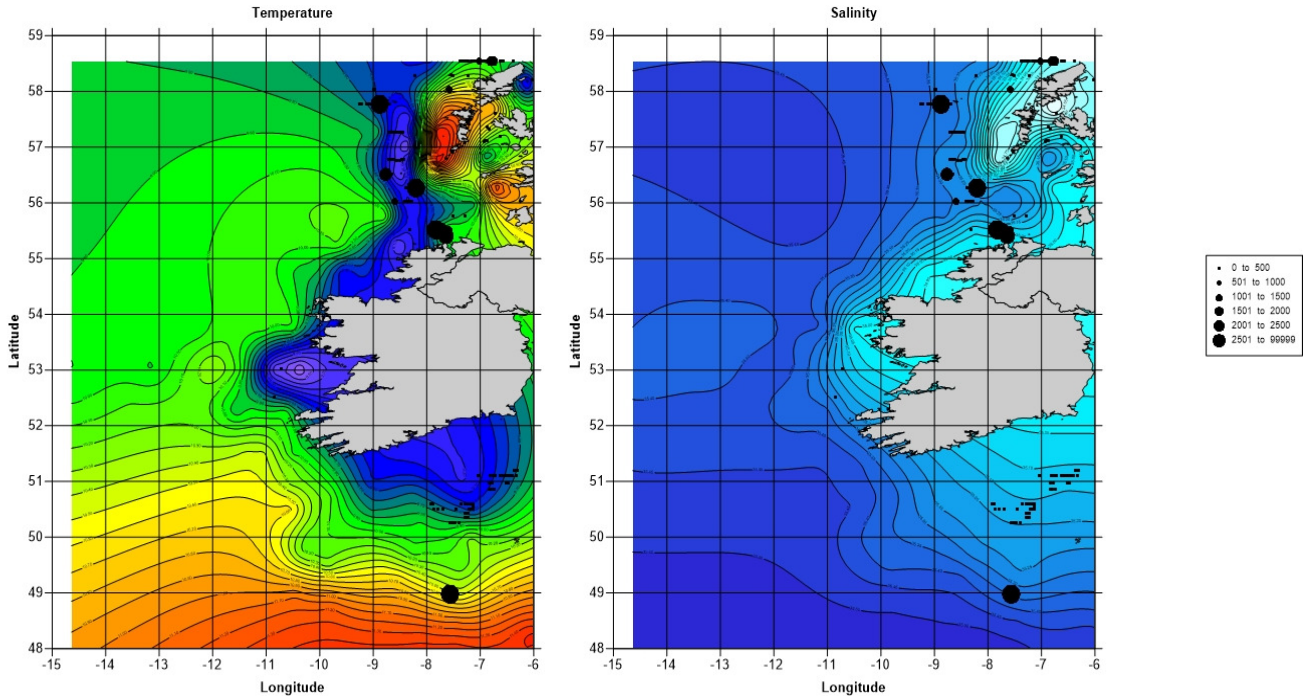



**Figure 17.** Habitat plots of temperature and salinity with herring distribution. Sea floor values overlaid with herring NASC values (black circles).

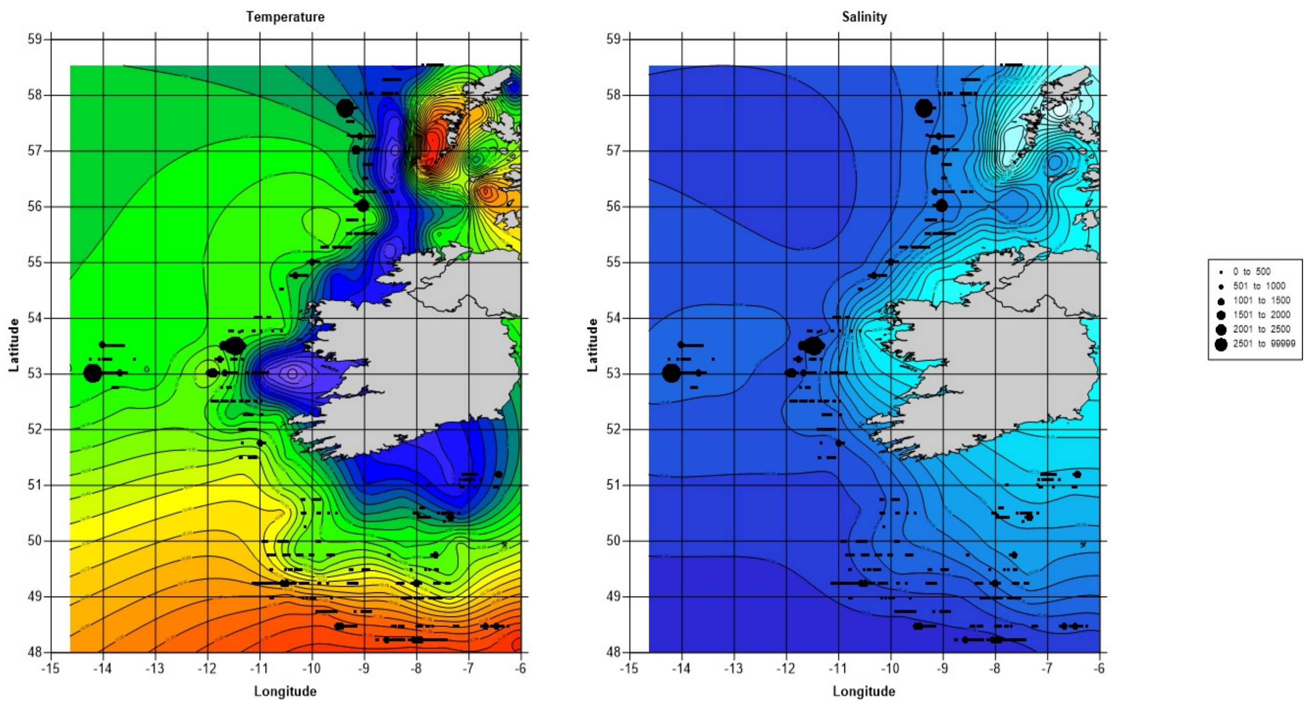



**Figure 18.** Habitat plots of temperature and salinity with boarfish distribution. Sea floor values overlaid with boarfish NASC values (black circles).

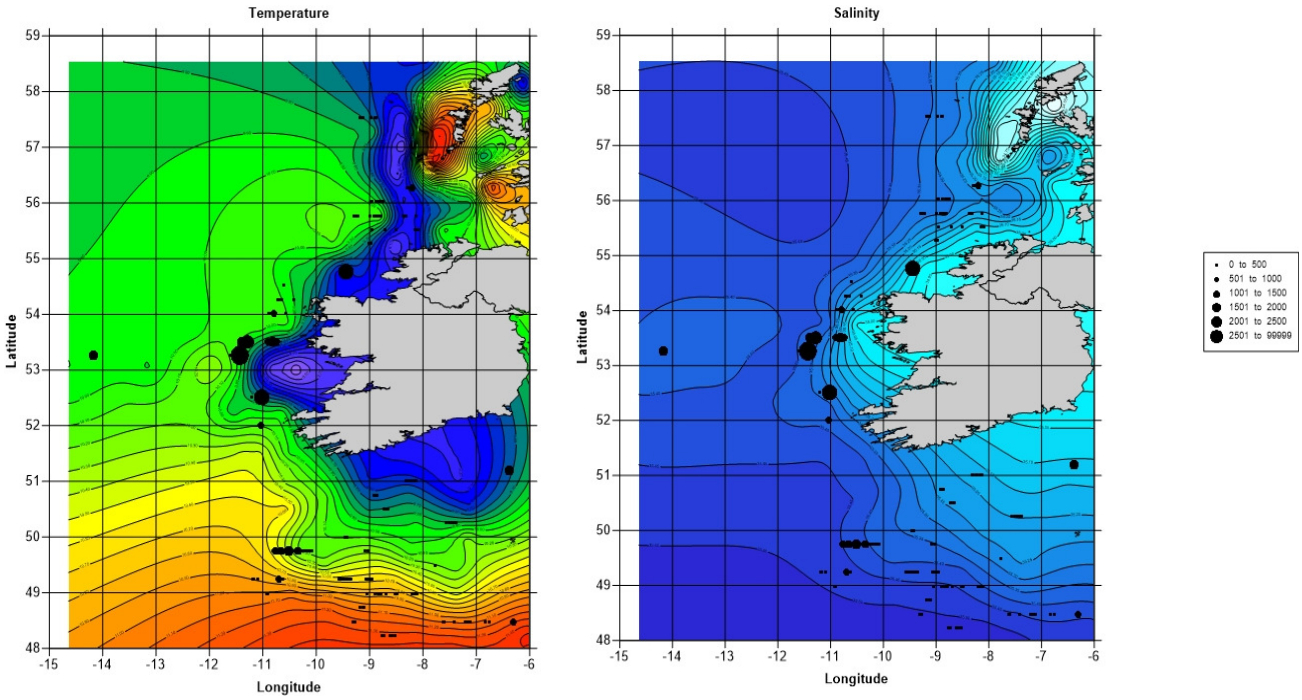



**Figure 19.** Habitat plots of temperature and salinity with horse mackerel distribution. Sea floor values overlaid with horse mackerel NASC values (black circles).

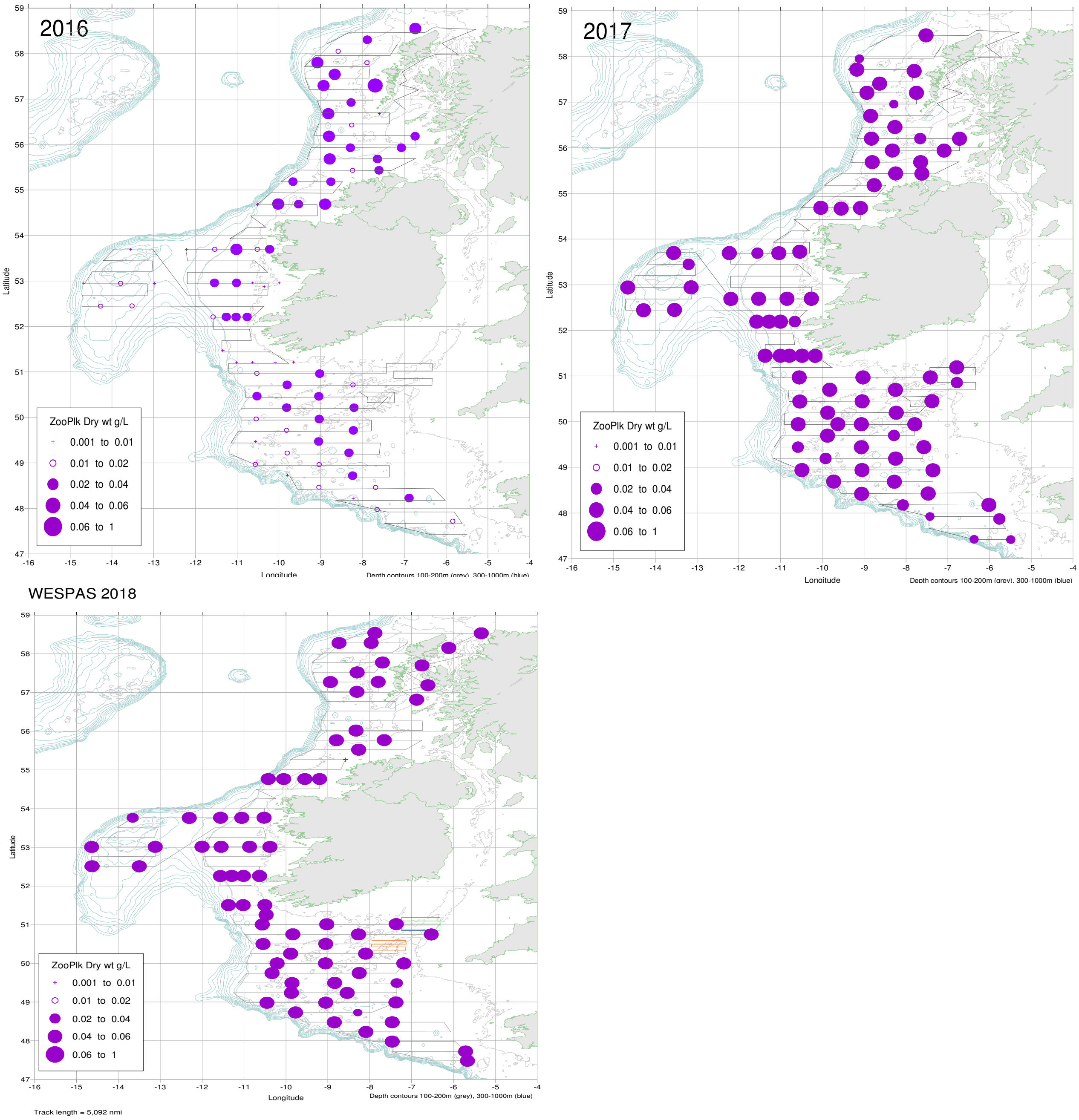



**Figure 20.** Zooplankton dry weight biomass by station (g dry Wt. m$^3$) 2016-2018.

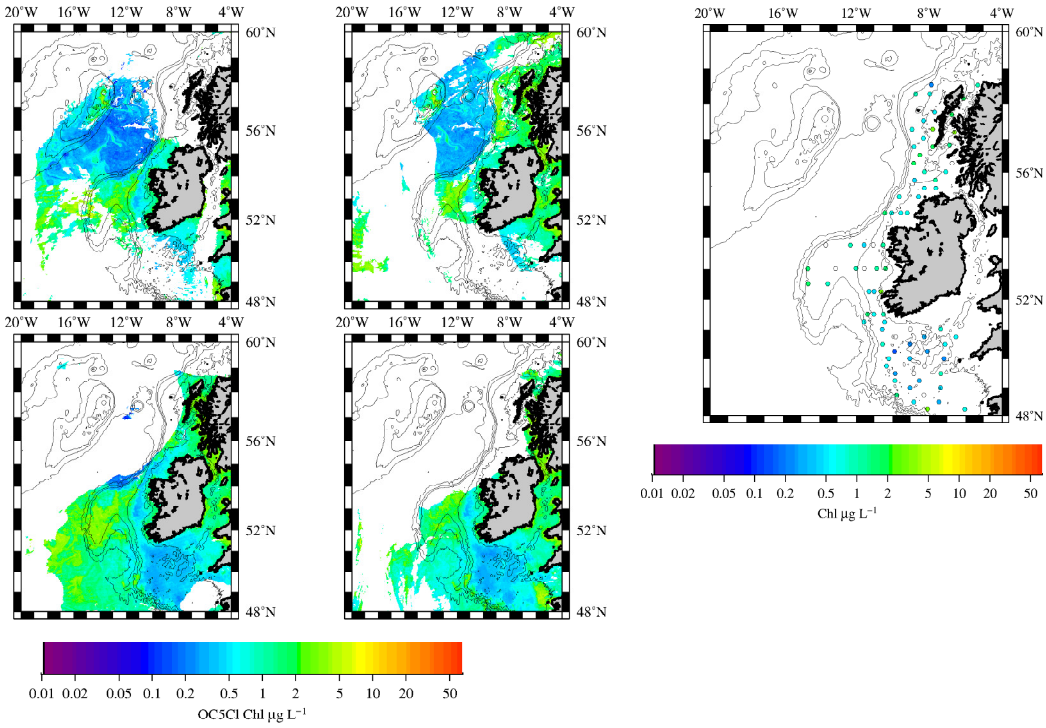



**Figure 20.** Left panel: OC5CI Chlorophyll images from June 27, 28, 29 and 30 (Source: CMEMS). Right panel: Near surface mixed layer chlorophyll measurements during WESPAS 2018

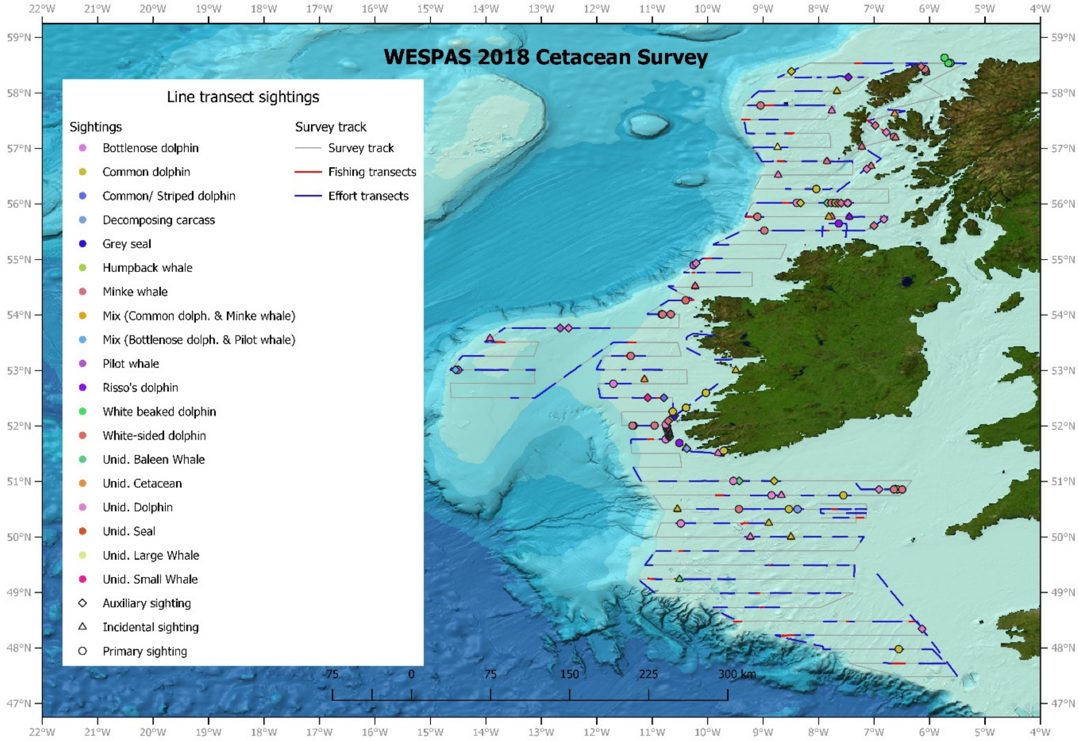



**Figure 22.** Distribution of marine mammal sightings while on-effort profiled with observer effort.

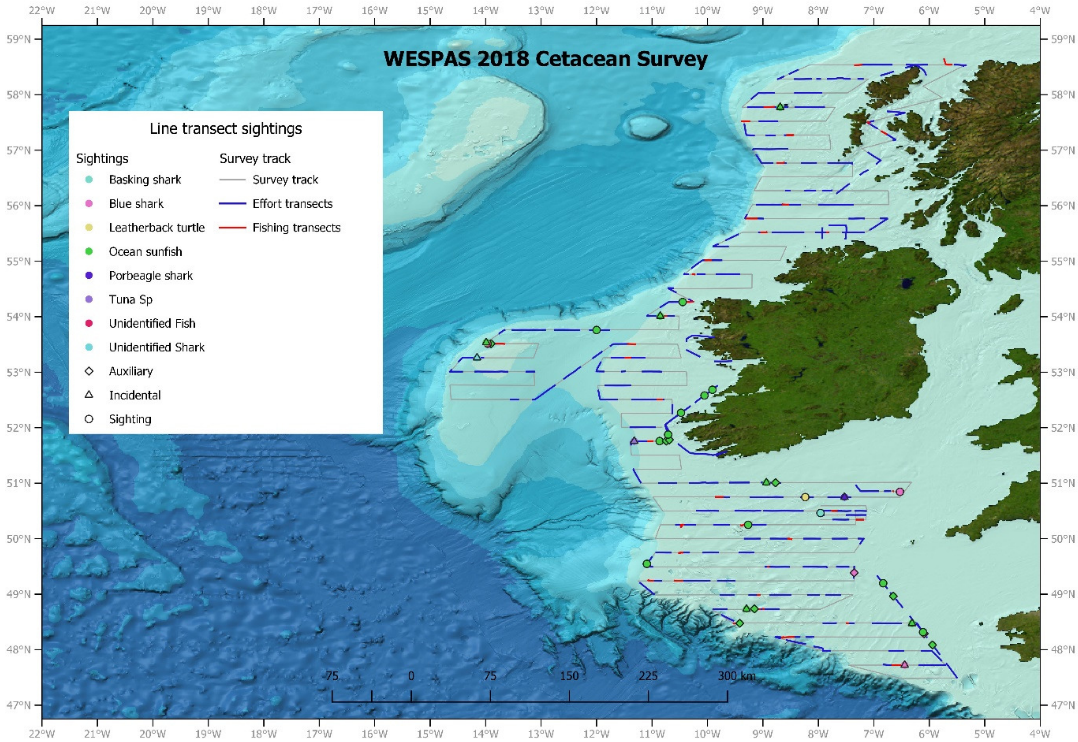


**Figure 23.** Distribution of marine megafauna sightings during the survey profiled with observer effort.

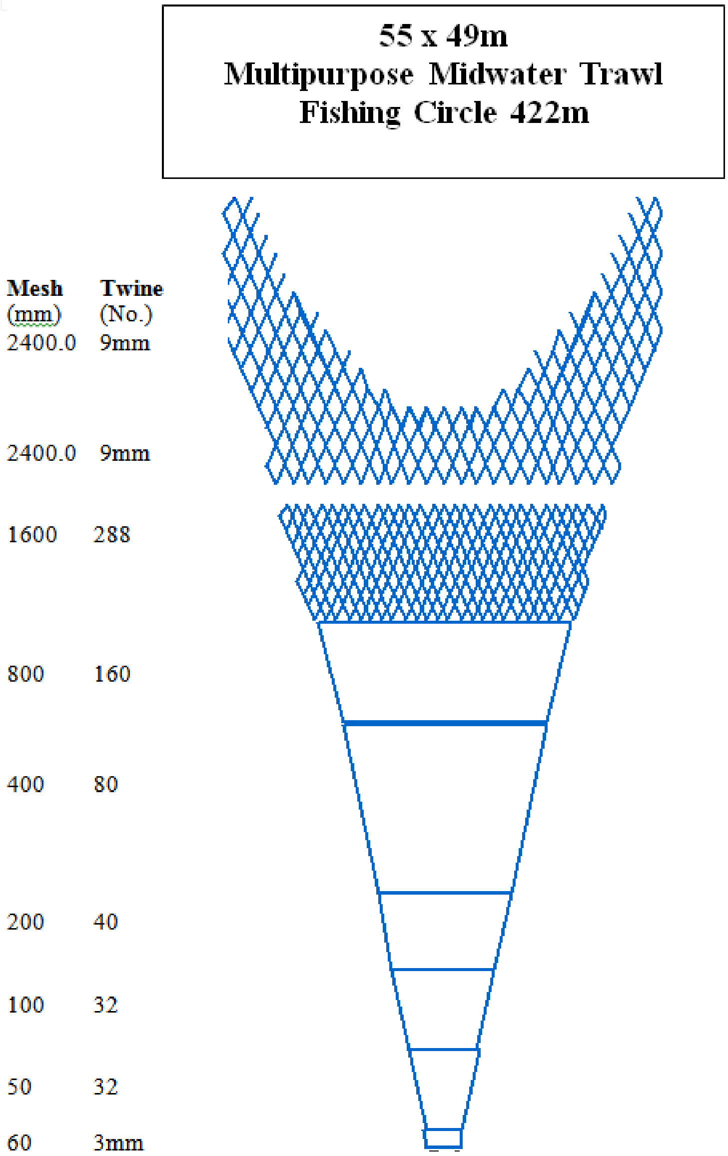



**Figure 24.** Single multipurpose midwater trawl net plan and layout.

Note: All mesh sizes given in half meshes; schematic does not include 32m brailer.

# Annex 4: List of presentations

**Preliminary results from the ECOCADIZ 2018-07 (31 July – 13 August 2018) and ECOCADIZ-RECLUTAS 2018-10 (10 – 29 October 2018) Spanish acoustic surveys**

Ramos, F., Tornero, J., Baldó, F., Jiménez, M.P., Díaz, P., Gago, J., de la Cruz, A., Sánchez-Leal, R.

Two acoustic surveys, one in summer (ECOCADIZ 2018-07; 31st July-13rd August; R/V Miguel Oliver) and another in autumn (ECOCADIZ-RECLUTAS 2018-10; 10th-29th October; R/V Ramón Margalef) have been conducted this year by the Spanish IEO, both surveying the Gulf of Cadiz Portuguese and Spanish shelf waters (20-200 m depth). The overall objective of both surveys is the acoustic assessment (by echo-integration) and mapping of neritic fish resources and of the oceanographic and biological conditions off the Gulf of Cadiz continental shelf. The autumn survey also provides acoustic estimates of anchovy and sardine juveniles (age 0). Regarding the summer survey, the whole acoustic assessment ((echogram scrutiny, total NASC allocation by species, computation of acoustic estimates) has had to be repeated shortly before the WG because of the previous detection of a possible misallocation of the total NASC by species. The resulting total NASC attributed to the "pelagic fish assemblage" reached its historical maximum. For the abovementioned time constraints, (size- and age-based) anchovy and (size-based) sardine acoustic estimates of abundance and biomass are the only available estimates provided to this working group. Both species showed remarkable increases in their respective population levels, more markedly in sardine. The detection in shallower waters of the central part of the surveyed area of many very dense sardine schools may be the main cause for such high population estimates. Acoustic data from the autumn survey are still processing and no result may be provided to the WG. As a novelty, this autumn survey has been conduct-ed using for the first time the new EK80 echo-sounder (working in a CW mode).

**PELAGO18 acoustic survey in the Atlantic Iberian Waters ICES area 9a (River Minho - Cape Trafalgar)**

Pedro Amorim and Vitor Marques and Maria Manuel Angélico

PELAGO18 survey was carried out onboard RV "Noruega" from 26th April to 1st June 2018. The main objective of the PELAGO18 survey was to describe the sardine and anchovy spatial distributions and to estimate their abundance off the Portuguese and the Spanish Gulf of Cadiz shelves. The estimated sardine biomass was 172 thousand tons for the whole area, representing a significant increase in relation to the PELAGO17 survey (81 thousand tons) and a similar estimate to the one obtained during the PELAGO16 survey (172 thousand tons) but with different partition between zones. The OCS zone was the area where the strong-est increase of biomass was observed, the 2018 estimate was three-fold higher than the one obtained during the PELAGO17. A considerable increase in the sardine biomass, mainly small fish, was also observed in the area of Cadiz Bay. There was also a raise in the anchovy biomass, in the whole area, in relation to the PELAGO17 survey (78 thousand tons in 2018, comparing with 29 thousand tons in 2017) but it was mainly due to the contribution of the fish in the OCN zone, where large schools of the species were observed. Accordingly, the anchovy egg abundances obtained with the CUFES system were very high for the NW region. The density was in fact the highest of the whole time series, the anchovy eggs represented 75% of the total eggs collected and 44% were in the NW shelf. Sardine eggs represented only 8% of the total eggs in the CUFES samples and 43% were observed in the NW. The proportion of anchovy versus sardine eggs in 2018 is also partially a consequence of the survey timing, mainly during May, when the sardine spawning season is closer to its end whereas the anchovy season is well underway.

**DEPM sardine Issues in ICES 9a in 2017.** María Manuel Angélico. **See details in section 5.3.2**

**PELGAS18 acoustic survey: abundance indices by acoustics in the Bay of Biscay**

E. Duhamel, M. Doray, M. Huret, F. Sanchez, T. Marie-Lepoittevin, H. Peltier, M. Authier

An acoustic survey (PELGAS) is carried out every year in the Bay of Biscay in spring onboard the French research vessel Thalassa. The objective of PELGAS survey is to study the abundance and distribution of pelagic fish in the Bay of Biscay. The main target species are anchovy and sardine, but they are considered in a multi-specific context and within an ecosystemic approach as they are located in the centre of pelagic ecosystem. The Pelgas18 acoustic survey has been carried out with good weather conditions (low wind) for the whole area, from the South of the Bay of Biscay to the west of Brittany. The help of commercial vessels (two pairs of pelagic trawlers) during 17 days provided about 120 identification hauls.

Warming and thermal stratification were slow in the beginning but then accelerated in the second fort-night of May. Salinity was low over the whole shelf especially within the 100m isobath, with values often below 33psu. This low salinity is due to a very rainy winter before the survey. Cumulated river discharges to the Bay of Biscay have been really large.

The PELGAS18 survey observed a relatively high level of anchovy biomass (185 500 tons), which seems to be higher to previous year, and comparable to 2012.The biomass estimate of sardine this year is 265 500 tons, which constitutes a decrease from last year, the biomass reaching a medium level of the PELGAS series.

**Integrating oceanographic, pelagic fish and predator data to advance ecosytem-based monitoring**

Maite Louzao, María Santos, Guillermo Boyra, Amaia Astarloa, Isabel García-Barón, Udane Martínez, An-na Rubio, Guillem Chust, Xabier Irigoien and Unai Cotano

Monitoring and management progresses have been made in the JUVENA annual surveys due to the need of an ecosystem-based assessment and management required by frameworks such as the Marine Strategy Framework Directive (Directive 2008/56/CE). The present study is a good example of such an effort by integrating not only pelagic fish species, but also marine megafauna monitoring and oceanographic characterisation in annual oceanographic surveys of the Bay of Biscay. Here, we present a species-specific approach to understand pelagic seabird 3D environment from multidisciplinary oceanographic cruises (Louzao et al. in press) and a community level approach to disentangle predator - prey networks in the pelagic eco-system of the Bay of Biscay (Astarloa et al. unpublished). In the species-specific approach, we developed generalised additive models to disentangle the effects of the 3D ocean environment and prey scapes at different depth ranges, in addition to static variables, on driving the spatial abundance of highly migratory seabirds, sooty (*Ardenna grisea*, SOSH) and great shearwaters (A. gravis, GRSH). Our results highlight that both species integrate marine resources at different vertical and spatial dimensions, influenced by different topographic features, oceanographic conditions and preyscapes. In the community approach, we explored the structure and the key interactions of the pelagic community by analysing the co-occurrence patterns of top predators (seabirds and cetaceans) and their prey (mainly pelagic fishes) in relation to regional oceanography. Both studies provide examples of the combination of multiple pelagic components to provide an integral assessment to advance ecosystem-based monitoring.

**Acoustic surveying of anchovy Juveniles in the Bay of Biscay: JUVENA 2018 Survey Report.**

Guillermo Boyra

The project JUVENA aims at estimating the abundance of the anchovy juvenile population and their growth condition at the end of the summer in the Bay of Biscay. The survey was coordinated between AZTI and IEO. AZTI leaded the assessment studies and IEO leaded the ecological studies. The survey took place in two research vessels: the Ramón Margalef and the Emma Bardán. The biomass of juveniles esti-mated for 2018 is around 489,708 tonnes, which represents a medium high estimation, ~70 % over the av-erage.

**BIOMAN survey 2018**

M. Santos, L. Ibaibarriaga, M. Louzao, and A. Uriarte

The research survey BIOMAN 2018 for the application of the Daily Egg Production Method (DEPM) in the Bay of Biscay anchovy was conducted in May 2018 from the 7th to the 28th covering the whole spawning area of the specie. Two vessels were utilized: The R/V Ramón Margalef to collect the plankton samples and the pelagic trawler Emma Bardán to collect the adult samples. During the survey 723 vertical plankton samples were obtained (PairoVET), 1,721 horizontal plankton samples (CUFES) and 41 pelagic trawls were performed. Moreover, 8 samples were obtained from the commercial fleet and 2 from Pelgas. In total, there were 47 samples for the adult parameters estimate.

12% of the total anchovy eggs were found in the Cantabrian Coast. The survey arrived until 6º20’W the most west longitude ever reached in the historical series. There were eggs all over the French platform, until 200m depth, up to 47º22’N were the limit was found. The weather conditions during the survey were good in general with a mean Sea Surface Temperature of 15.2ºC and a mean sea surface salinity of 34.41.

Total egg production (Ptot) for anchovy was calculated as the product of spawning area and daily egg production rate (P0), which was obtained from the exponential decay mortality model fitted as a Generalized Linear Model to the egg daily cohorts. The adult parameters, sex ratio (R), batch fecundity (F), spawning frequency (S) and weight of mature females (Wf), were estimated based on the adult samples obtained during the survey. Consequently, the total Biomass obtained for anchovy resulted in 192,088 t, the highest of the series, with a coefficient of variation of 12%. Total egg abundance of sardine at ICES 8abd without the North part was 4.79 E+12 eggs, lower than last year estimate (6.0 E+12) and the historical mean (5.92 E+12) for that area.

This is the third year were sights were achieved. Marine mammals, seabirds, human activities & debris were recorded by one observer. And the second year were eDNA and microplastics were surveyed, looking for an ecosystem survey approach.

**PELTIC2018: Pelagic ecosystem survey in western Channel and eastern Celtic Sea.**

J. van der Kooij, S. Rodríguez Climent, F. Campanella and J. Silva

Preliminary results for the 2018 Peltic survey were presented to the working group, only a week after completion of the survey. Peltic18 constituted the 7th autumn survey on small pelagic fish and their ecosystem in the waters of the western English Channel and eastern Celtic Sea. This year, for the second year, the survey was extended beyond the area covered between 2012 and 2016, which focussed solely on the Mackerel Box. As in 2017, survey coverage also included the French waters of western Channel (ICES 7e), and for the first time part of the Eastern Channel (7d). The survey commenced on the 6th of October and ran for 36 effective survey days, starting in the Bristol Channel working into the English Channel. In total 2200 nautical miles of effective acoustic coverage were covered and supplemented with 46 valid trawls which provided details on species composition and biological information. Both the number of completed acoustic transects and trawls exceeded those achieved in 2017, despite having more weather induced downtime in 2018. The (preliminary) results indicated that there were some differences in ichthyofauna observations compared to the previous extended survey in 2017. In the Bristol Channel, other than the usual high biomass concentration inside the estuary, the majority of fish biomass was found in medium depths, rather than at the deepest parts of the transects. In the French waters of the western Channel more fish activity was found along the western-most transects although further east in the western channel, very few schools were encountered, matching last year's results. The eastern Channel, sampled for the first time during the Peltic series, yielded little fish biomass and sardine dominated the ichthyofauna. Sardine biomass was found north of the Cornish Peninsula and in good numbers in the English Channel. Sardine egg densities were more widespread compared to 2017 with high concentrations across the west-ern stations from north of the Cornish Peninsula to the French coast. Anchovy was more widely distributed than in recent years and biomass was up significantly compared to 2017. Although widespread, sprat bio-mass was down from 2017 across the survey area including also in Lyme Bay (English Channel). Herring (*Clupea harengus*), normally only found only mixed in with sprat in a handful of Bristol Channel stations, contributed to all but one of stations north of the Cornish Peninsula and in several trawls in large numbers. The majority of fish were age 0. For the first time in the survey series (started in 2012), Atlantic bonito (*Sarda sarda*) were caught. A total of ~100 0-group specimens at 4 different trawls stations (Bristol Channel and Lyme Bay) were caught ranging between 15 and 30 cm. Of note was the continued increase in Atlantic bluefin tuna observations. Despite the very hot summer, oceanographic conditions in October were comparable to the average values of the time series.

**Western European Pelagic Acoustic Survey (WESPAS) survey 2018**

Ciaran O'Donnell

The survey took place over 42 days beginning on the 10th June and continuing until the 24th July, 2019. The objectives of the survey were carried out successfully and as planned. The objectives of the survey were carried out successfully and as planned. Good weather conditions dominated during the survey allowing for extended marine mammal and seabird survey effort. No weather induced downtime was recorded. Comprehensive trawling was carried out over the course of the survey (n=42) providing good confidence in school recognition and supporting biological data for age stratified abundance estimation of target species (herring, boarfish, horse mackerel).

Herring were distributed further south in 2018 compared to 2017, with some herring south of 56°N, particularly young fish (1- and 2-wr). There was very little herring distributed south of 56°N in both 2016 and 2017. Malin Shelf herring biomass was ~18%

higher in 2018 compared to 2017. The distribution of boarfish was comparable to 2017 and earlier years in the time series except for the northern region. The northern distribution of the stock was observed to extend almost continuously, albeit it in low abundance, northward of 59°N north. Cohort tracking was poor and likely due to the application of an age length key to assign ages to biological samples as opposed to actual survey ages. Horse mackerel were distributed in comparable regions along the Irish west coast, Porcupine Bank and Celtic Sea. Geographical distribution was thus comparable to previous surveys, but the number and acoustic density of aggregations was lower than in 2017, but more comparable to 2016, in this as yet short time series.

Survey effort, timing and area coverage were comparable to previous years and the same vessel and sampling equipment (transducers and trawl) were used. The survey cruise report is available for download at: http://hdl.handle.net/10793/1380

**WKMesoMETH**

Ciaran O'Donnell

**Workshop on the development of practical survey methods for measuring and monitoring in the mesopelagic zone (WKMESOMeth).**

Details of the workshop and terms of reference are available at: http://www.ices.dk/community/groups/Pages/WKMESOMeth.aspx

The ICES Working Group on Fisheries Acoustics, Science and Technology (WGFAST) invites survey and re-search scientists to contribute to the development of methods to undertake acoustic measurements and biological sampling of animals within the mesopelagic zone. In a global context, open ocean surveys have the potential to contribute to the regular monitoring of key mesopelagic fish species but can lack the procedures and technology necessary to provide meaningful, ongoing measurements. The potential of using existing survey activities for mesopelagic objective needs assessing, technology and methodologies require consideration, and limitations need to be addressed.

The aim of the workshop is to explore research currently underway in the mesopelagic zone, document existing surveys undertaking measurements and determine practical methods for meaningful monitoring programs from established survey programs.

Participants are encouraged to contribute to the following topics:

- Provide details on current open ocean surveys with the capacity to undertake, or currently undertaking acoustic measurements and biological sampling of animals within the mesopelagic zone

- Provide example data and research findings for discussion to determine what is achievable from de-scribed vessel, platform and vehicle-based surveys for the development of mesopelagic biomass monitoring programs

- Development of methods to monitor the abundance mesopelagic fishes given the complexity involved and equipment currently in use

- Determine the minimum requirements in terms of resources, hardware, additional research knowledge, analysis methodology, and sampling equipment required for meaningful abundance measurements, and determine the components of the mesopelagic zone to which this applies

The workshop on the development of practical survey methods for measuring and monitoring in the mespelagic zone (WKMESOMeth) will be hosted at the Marine Institute, Galway, Ireland, 27-28 April 2019.

For more information contact ciaran.odonnell@marine.ie or gavin.macaulay@hi.no

**Italian Acoustic survey in Adriatic Sea - MEDIAS in the western GSA 17 and GSA 18**

Iole Leonori, Andrea De Felice, Ilaria Biagiotti, Giovanni Canduci, Ilaria Costantini, Sara Malavolti, Nicola Canduci

Pan-MEDiterranean International Acoustic Surveys (MEDIAS) are aimed at estimating abundance and bio-mass of anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) in several areas of the Mediter-ranean Sea. Actually, MEDIAS surveys are performed in GSAs 1 and 6 (Northern Alboran Sea & Northern Spain), GSA 7 (Gulf of Lion), GSAs 9 & 10 (Ligurian Sea, North & South Tyrrhenian Sea, officially MEDIAS surveys since 2017), GSA 16 (South of Sicily), GSAs 17 & 18 (Northern & Southern Adriatic Sea), GSAs 20 and 22 (Eastern Ionian and Aegean Seas).

The 2018 acoustic survey was carried out in June-July in western GSA 17 and GSA 18 including territorial waters of Slovenia (Dr. Tomaz Modic took part in the cruise in Slovenian waters). Acoustic data were logged over a grid of systematic parallel transects perpendicular to coastline/bathymetry. Inter-transect distance was 8-10 nmi. Acoustic monitoring was done during daytime (6:00 am – 7:00 pm). Scientific echosounder: Simrad EK60 equipped with 38 and 200 kHz and EK80 with 70 and 120 kHz, hull-mounted split beam transducers. The research vessel was "G. Dallaporta" (built 2001, 35.30 m, 285 GT, 1100 CV). Vessel speed during acoustic survey was 9.5 knots. The acoustic system was calibrated in July 2018 using the standard sphere method (Foote et al., 1987; Demer et al., 2015). Elementary Sampling Distance Unit (EDSU) was 1 nmi, minimum bottom depth 10 m, pulse duration 1 ms for all frequencies and ping rate was set to maximum.

In 2018, in western GSA 17, total nautical miles acoustically monitored (including pelagic trawls tracks and linking transects) were 1490 for a total area of 10636 nmi2, in western GSA 18 total nautical miles were 391 for a total area of 2510 nmi2. Total area extension was about 13200 square nautical miles in the western part of Adriatic Sea, that rise up to 15700 square nautical miles including the Montenegro and Albania survey, thus ensuring a strong synopticity to the monitoring of such a large area.

In detail, the MEDIAS acoustic survey in western GSA 17 was conducted in June-July 2018; the coverage of the area was 100%, 35 pelagic trawls were conducted, 81 CTD stations were made and in 45 stations out of them plankton sampling by means of WP2 net (mesh size 200 μm) was carried out.

The MEDIAS acoustic survey in western GSA 18 was carried out in July 2018; area coverage was 100%, 11 pelagic trawls were conducted and 58 ichthyoplankton stations to apply Daily Egg Production Method were made, combining CTD and plankton net sampling. MEDIAS extension in eastern GSA 18 (Montenegro and Albania) could not be carried out in July 2018 for the small amount of days of ship availability and prolonged bad weather conditions.

Since 2018 data elaboration is not yet finished, the results are updated until 2017. In the last period biomass estimations of anchovy (Engraulis encrasicolus) and sardine (*Sardina pilchardus*) stocks in western Adriatic Sea saw severe decreases both in GSA 17 in 2016 and in GSA 18 in 2015. While anchovy in west GSA 17 in 2017 presents an increase up to 2015 levels, sardine remains at rather low biomass values as in 2016 and in the years before 2011. In west GSA 18 anchovy and sardine biomass remain low since 2015 even if a slight increase is recorded in 2017.

Spatial distribution of anchovy and sardine in western Adriatic Sea in 2017 is mainly coastal, especially for sardine, with higher values in the northern area for both species.

**DCF-MEDIAS 2017. - Acoustic survey in the eastern part of the Adriatic Sea (GSA 17) – Croatia**

Vjekoslav Tičina and Tea Juretić

Croatian acoustic survey, as of part of EU-MEDIAS 2017, covering the eastern part of the GSA 17 (Adriatic Sea) was the 5th acoustic survey in this area performed within EU-DCF. Acoustic survey in 2017. successfully covered 100% of total area of eastern part of the Adriatic Sea that need to be covered within Croatian DCF. In total, 32 vessel days were used for this purpose. Oceanographic description of the survey area during late August-September 2017. have been based on grid of 89 CTD stations. In line with MEDIAS protocol, target species were anchovy (Engraulis encrasicolus) and sardine (*Sardina pilchardus*).

Acoustic indices for anchovy indicate slight decrease in biomass in August-September 2017 compared to September-October 2016. in eastern part of the Adriatic Sea. Recruitment was very low also. Fish from age group 1 showed the highest portion in biomass distribution by age. Spatial distribution indicated very low abundance in the northern part of surveyed area, along western Istrian coast, where unusual occurrence of ctenophora Mnemiopsis leidy was observed during the survey. At the same time, biomass and abundance indices for sardine indicated slight increase in August-September 2017 compared to September-October 2016. in eastern part of the Adriatic Sea. Fish from age group 0 showed the highest portion in biomass by age, indicating a good recruitment of sardines in 2017. If both target species are considered together, it seems that their overall biomass (anchovy & sardine combined) present in eastern part of the Adriatic Sea in September slightly increased from 2016. to 2017.

Total egg production (Ptot) for anchovy was calculated as the product of spawning area and daily egg pro-duction rate (P0), which was obtained from the exponential decay mortality model fitted as a Generalized Linear Model to the egg daily cohorts.

The adult parameters, sex ratio (R), batch fecundity (F), spawning frequency (S) and weight of mature females (Wf), were estimated based on the adult samples obtained during the survey. Consequently, the total Biomass obtained for anchovy resulted in 192,088 t, the highest of the series, with a coefficient of variation of 12%. Total egg abundance of sardine at ICES 8abd without the North part was 4.79 E+12 eggs, lower than last year estimate (6.0 E+12) and the historical mean (5.92 E+12) for that area.

This is the third year were sights were achieved. Marine mammals, seabirds, human activities & debris were recorded by one observer. And the second year were eDNA and microplastics were surveyed, looking for an ecosystem survey approach

**MEDIAS Greece (& other work) - Aegean Sea and east Ionian Sea. Hellenic Centre for Marine Research - Institute of Marine Biological Resources and Inland Waters (IMBRIW)**

Zacharias Kapelonis

Hellenic Centre for Marine Research performs acoustic surveys in GSA 20 (east Ionian Sea) in June-July and 22 (Aegean Sea) in September-October. In the Aegean Sea survey, concurrent sampling is performed for the Daily Egg Production Method (DEPM) to estimate Spawning Stock Biomass (SSB). R/V PHILIA of HCMR is used to perform all surveys with a hull mounted SIMRAD EK80 (since 2016) utilizing four frequencies (38, 120, 200 and 333 kHz).

In 2016, the biomass estimation for Aegean (June) was 77531 t for Anchovy and 31077 t for Sardine. For the same year, the biomass estimates in east Ionian Sea (September) were 20008 t for Anchovy and 3758 t for Sardine. In 2017 survey was performed only in east Ionian Sea (during October) and biomass estimations were 20466 t for Anchovy and 7999 t for Sardine. The east Ionian Sea survey for 2018 was underway at the time of the WGACEGG 2018 meeting.

Habitat modelling is used for the study of essential fish habitats, including the spatio-temporal distribution and changes of biomass and nurseries for Anchovy and Sardine (2013-2016, PROTOMEDEA project), and, in collaboration with other MEDIAS groups, the identification of potential nursery grounds of the Atlantic Mackerel in the Mediterranean Sea (Giannoulaki et al. 2017).

After the recent upgrade of the echosounder system, HCMR has also begun looking more into the meso-pelagic assemblages which appear at various locations of the surveyed GSAs. Dedicated to this cause, pro-ject MESEBED (mesobed.hcmr.gr) begun recently to study at least three locations in the two surveyed GSAs; the first cruise of the project was performed jointly with MEDIAS in the Corinthian Gulf (GSA20), and completed a few days prior to WGACEGG 2018.

Giannoulaki et al. 2017, Habitat Suitability Modelling to Identify the Potential Nursery Grounds of the Atlan-tic Mackerel and Its Relation to Oceanographic Conditions in the Mediterranean Sea, Frontiers in Marine Science, Vol. 4 (DOI:10.3389/fmars.2017.00230)

**Anchovy and sardine spatio-temporal distribution and habitats in the European Atlantic Area, based on WGACEGG gridded maps**

Mathieu Doray

Multiple Factorial Analysis (MFA) (~ PCA on grouped data) was performed on the gridded maps produced by WGACEGG, to analyse the anchovy and sardine spatio-temporal distribution and habitats in the Euro-pean Atlantic Area (EAA). Data matrices were formed with gridded maps cells as rows, and annual parame-ter values as columns, grouped by years and submitted to MFA. MFAs were performed on gridded maps from spring acoustic surveys describing: i) environment (SST and SSS), and ii) fish (anchovy and sardine) acoustic densities (NASC), over the 2004-2008, 2010-2011, 2013-2017 time period. Environment and fish variables were summarised by their two first MFA loadings (MFA1&2). Relationships between fish and environment MFA1&2 were explored to assess the potential environmental drivers of fish distributions. Environment MFA1 (43% var. expl.) was positively correlated with SSS, and frequently with SST. Higher SSS and sometimes SST were observed in southern areas, offshore Biscay and Cantabrian Sea. Environment MFA2 (29% var. expl.) was consistently positively correlated with SST. Higher SST values were observed in coastal Biscay and southern areas. No significant warming trend was found in SST at this time of the year. Anchovy and sardine NASC were consistently correlated with fish MFA1 (48% var. expl.). Persistent core distribution areas of anchovy and sardine were SW Iberican and Southern Biscay areas (MFA1>0). Sardine NASC was correlated with MFA2 (15% var. expl.). Higher sardine densities were observed in Western Iberican and North coastal Biscay areas until 2007 (MFA2>0). After 2007, MFA2 loadings averaged over the whole area, i.e. a proxy for sardine NASC, has dropped. Environment MFA1&2 explained 3% and 53% of fish MAF1, respectively (linear model). Anchovy and sardine habitats were then characterised by higher SST in southern areas and coastal Biscay. Fish MFA2 was not explained by environment MFA1&2 (linear model). Fish landings in area 9 however explained 67% of fish MFA2 in W. Iberican area (Generalised linear model, Gamma family, log-link). In conclusion, this study is the first synoptic assessment of anchovy and sardine habitat extension and occupation variability at the European Atlantic Area scale. MFA1&2 derived from fish and environment datasets proved to be useful proxies to summarise spatial and temporal varia-bility of ecosystem components. Anchovy and sardine large scale distribution was correlated with relatively higher SST in southern Iberican and coastal Biscay areas. Sardine higher densities in western Iberican and offshore northern Biscay areas were not explained by available environmental indices. Landings seem to have had a significant effect on decreasing sardine densities in Western Iberican area.

**WGACEGG gridded maps database consolidation, hosting and valorisation**

Mathieu Doray

WGACEGG members agreed to consolidate time series of survey indices and gridded maps and to host them in an instance of the EchoBase relational database hosted at Ifremer.

It was also agreed to: i) publish datasets extracted from the database in the ICES dataset archive when this service is available, ii) link the WGACEGG database to the ICES map service, to allow for the display of WGACEGG gridded maps together with other data stored in the ICES acoustic and trawl database.

All data providers but IPMA agreed to adopt the ICES metadata convention for processed acoustic data and the ICES data portal for acoustic trawl surveys data storage. IPMA representatives were not entitled to agree on these terms and had to refer internally first.

**Survey bias and precision**

Pierre Petitgas

The surveys coordinated by WGACEGG use two different observation methods (acoustics and eggs) on the same resources (sardine and anchovy). The estimates derived by the different methods do not always agree. In this context, the concepts of survey precision and bias were revisited by the group and a strategy discussed for further analysis.

Bias represents a systematic error, while precision relates to data variability. Bias originates from fish be-havior interacting with the survey protocol. It may vary between years. Survey bias cannot be estimated from the survey data alone. But variation in survey bias across years can be monitored using different sur-vey methods and in particular by combining acoustic and egg estimation methods. Even though the differences between estimates are not well understood, they can serve to construct a reliability index of the survey estimates. Also, an "ensemble" approach using the various survey indices could lead to a more ro-bust survey index. Another source of bias relies in the survey design. All areas should have equal sampling probability. Over sampling may lead to bias if data are not analyzed properly. Stratification of the data can be a solution, depending on the situation. By contrast, survey precision can be estimated from the survey data alone as it depends on data number and variability. Survey precision may be estimated using classical statistics or geostatistics. Classical statistics is a design-based approach, where the data locations need be randomized. This allows to estimate population abundance with no hypothesis on the surveyed popula-tion. In contrast, geostatistics is a model-based approach, where spatial autocorrelation in the data is mod-elled. The advantage is that survey design can be regular, which is adapted for acoustic and egg surveys. In the CRR 338 (Handbook of geostatistics in R for fisheries and marine ecology), R scripts are available for estimating survey precision for different survey designs, including regular or random designs.

**PELACUS-IBWS-0318 survey report**

Pablo Carrera

The acoustic-trawl PELACUS started in 1991. Since 2013 is carried out on board R/V Miguel Oliver (MO). In addition, the surveyed area was extended from the 200 m isobath to the 1000 m one in order to make available the bulk of the blue whiting distribution.

In 2018, on account the Spanish duties related to DCF, the IEO has joined the International Blue Whiting Spring Survey (IBWSS). Therefore, the ICES Working Group of International Pelagic Surveys acknowledged this new collaborator and agreed B/O Miguel Oliver will cover the off-core spawning area located south-west of Porcupine Bank (e.g. Porcupine Seabight). This area was surveyed between 14th and 20th March, when the vessel sailed towards Santander harbour to start the normal PELACUS coverage. Nevertheless, it should be noted that due to time constraint, the grid was anticlockwise prospected, thus optimizing survey time but covering in opposite way as normally performed.

Weather condition was a big issue as most of the time the wind strength was higher than force 5 and waves about 2-3 as minimum. Several days were lost because the adverse weather condition, thus conditioning the normal development of the survey. 2 tracks in the Spanish area were not steamed while other 4 were partially covered.

First survey (IBWSS) was carried out between 14th and 20th March (excluding steaming days). On the other hand, PELACUS was done between 25th to 16th March. Around Porcupine area (covered during IBWSS), it was noticeable the abundance of pearlside, which was also found in important quanties in the Spanish area. In PELACUS, the strength of the Poleward Current seems to have been an important impact on the fish distribution: the bulk of the anchovy and sardine distribution was in the western part. As usually, mackerel was the most abundant fish species yielding up to 550 thousand tonnes. Due to the bad weather conditions, occurred in bottom layer, close to the coast. Sardine and anchovy were found in Galicia, with a significant increased from previous years. For the rest of the species, the lack of boarfish schools, the significant increase in distribution of pearlside together with the occurrence of few schools of juvenile blue whiting were the most noticeable findings.

**Characterization of Bay of Biscay sound scattering layers using broadband acoustics, nets and video**

Arthur Blanluet, Mathieu Doray, Laurent Berger, Jean-Baptiste Romagnan, Naig Le Bouffant, Sigrid Lehuta and Pierre Petitgas. **See details in section 5.3.1**

**Preliminary analysis of the effect of the ping rate on the average NASC**

Guillermo Boyra, Andrés Uriarte and Udane Martinez. **See details in section 5.3.1**

**Ex-situ TS measurements of European anchovy in a harbour cage**

Bea Sobradillo and Guillermo Boyra. **See details in section 5.3.1**

**Surface fish schools**

Mathieu Doray. **See details in section 5.3.1**

**Echosonde project and Phoenix project (including update on EK80)**

Mathieu Doray. **See details in section 5.3.1**

**ICES acoustic-trawl data portal**

Hjalte Partner. **See details in section 5.3.1**

**The use of the CUFES in acoustic surveys to estimate the egg abundance of mackerel (*Scomber scombrus*) and horse mackerel (*Trachurus trachurus*).**

P. Díaz, I. González and P. Carrera. **See details in section 5.3.2**

**A joint effort across marine laboratories for improving spawning frequency estimations in fishes.**

Ganias K, Charitonidou K., dos Santos Schmidt T.C., Alix, M., Mouchlianitis F.-A., Angélico M.M., Costa A.-M., Domínguez-Petit R., Garabana D., Korta M., Krüger-Johnsen M., Nunes C., Santos M., van Damme C.J.G.,Kjesbu O.S. **See details in section 5.3.2**

**Effect of ping rate on average NASC**

Guillermo Boyra. **See details in section 5.3.1**

**1D vertical model of eggs distributions – 1st step: Implementation**

Marina Chifflet & Maria Santos. **See details in section 5.3.2**

**Echosonde project**

Mathieu Doray. **See details in section 5.3.1**

**Multibeam echo-sounders for the study of shoal structure and stock evaluation**

Nans Burgarella, Laurent Berger, Mathieu Doray, Pierre Petitgas. **See details in section 5.3.1**

**IBERAS 1118 survey report**

Pablo Carrera

IBERAS is a new acoustic-trawl time series covering the existing gap between the coverage of JUVENA, JUVESAR and ECOCADIZ (e.g. Atlantic waters of 9a). The main objective of this survey is to estimate the strength of the sardine and anchovy recruitment. The former due to the low SSB, consequence of a long period of bad recruitment and high fishing mortality and the later due to the emergence of the Atlantic sub-population. Survey design was adapted to ensure a fine coverage of the main potential recruitment areas, with track 4 nmi apart in those areas, and 8 nmi apart in the rest of the surveyed area. The survey was carried out on board R/V Ramón Margalef (the same used in both JUVENA and ECOCADIZ) from 1st to 19th November. Due to the bad weather conditions, only 14 days were allocated for survey purposes. 26 fishing stations were carried out and 601 nautical miles were surveyed. Horse mackerel was found in 80% of the hauls, with anchovy as the most important fish species in terms of catches. Chub mackerel, sardine, horse mackerel and boarfish also occurred in important quantities. Although, no estimation was made, it should be highlighted the general aggregation pattern found, with most of the species occurred in big and thick schools, accounting for high quantities of backscattering energy. Anchovy occurred in shallower waters, and the most noticeable was a big school recorded near Figueira da Foz, with more than 7 nmi long an approx. 1 nmi wide and 20 m thick and very dense (-29.11 dB as mean sV value and the maximum found at -13.14 dB). Similar pattern was observed in chub mackerel and sardine, although their schools were significantly smaller than that recorded for anchovy. Accounting the length composition, it seems sardine recruitment will be at similar level of those of the previous years.

The results were promising although the bad weather conditions that limited the coverage of very shallower waters (between 20 and 14). Nevertheless, given the school occurrence, most of them could have been accessible. The presence of big schools is an issue when estimating the variance associated to the mean density. For this reason, the proposal for the next year (under discussion between IEO and IPMA and the national authorites) is to do this survey in September, at the same time of the JUVENA, on board of R/V Angeles Alvariño which has similar characteristics and equipment of those of R/V Ramón Margalef. Besides, the use of this vessel will allow MS70 be used; in such case both, near surface and near coast schools will likely be detected.

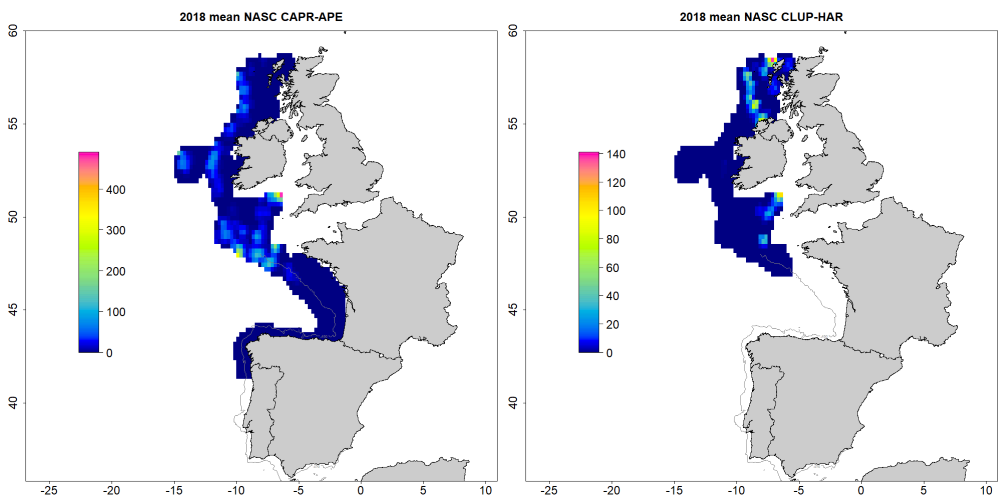
**ICES Transparent assessment framework**

Hjalte Parner, Colin Millar, Arni Magnusson

The ICES Transparent Assessment Framework (TAF) at https://taf.ices.dk aims to implement a framework to organize data, methods, and results used in ICES assessments, so they are easy to find and rerun later with new data. The framework follows a simple Input Model Output data flow, which enable documentation and version control of all steps and components used within the process.

## Annex 5.2. Distribution of eggs and adults of small pelagic fish in their environment in ICES sub-Areas 6, 7, 8 and 9

### Annex 5.2.1.4. Other adult pelagic fish species acoustic density distributions



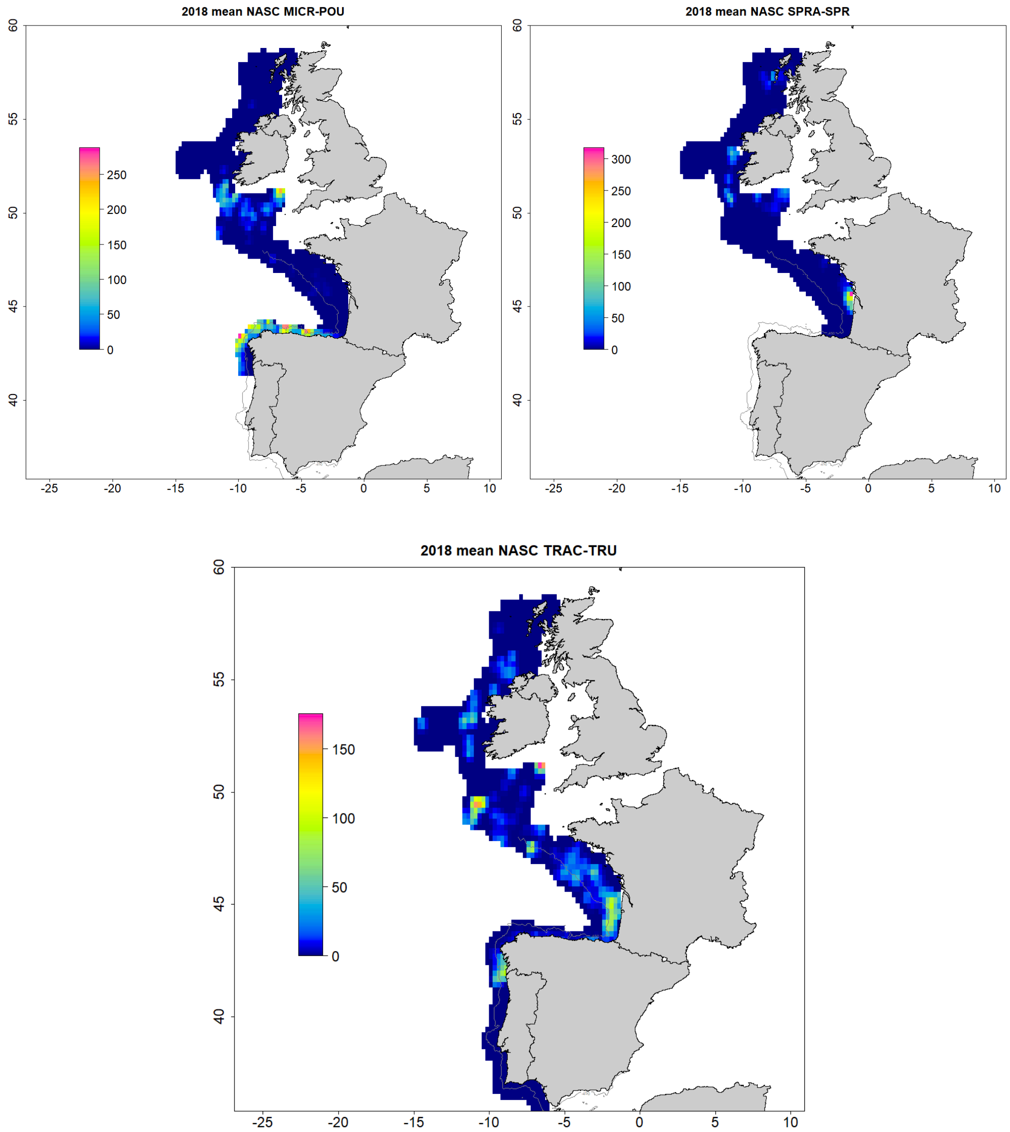



**Figure 5.2.1.4.7. Boarfish (CAPR-APE), herring (CLUP-HAR), blue whiting (MICR-POU), sprat (SPRA-SPR) and horse mackerel (TRAC-TRU) acoustic density (NASC, $m^2.NM^{-2}$) maps in sub-areas 6, 7, 8 and 9, derived from PELAGO, PELACUS, PELGAS and WESPAS spring surveys, 2018, 0.25° map cell.**

New gridded maps have been produced by combining data collected in 2018 during the spring acoustic surveys (PELAGO, PELACUS, PELGAS and WESPAS) on boarfish, herring, horse mackerel, sprat and blue whiting in sub-areas 6, 7, 8 and 9. These maps provide a unique synoptic overview of the distribution of those species in the European Atlantic Area from Spain to UK (**Figure 5.2.1.4.7.**). They will be produced in routine by the WGACEGG group.

## Annex 5.3: Methodological developments for acoustic and DEPM biomass assessment

### Annex 5.3.1 Methodological developments for acoustic biomass assessment

**Preliminary analysis of the effect of the ping rate on the average NASC.** G. Boyra, A. Uriarte and U. Martinez

The recent increase in interest in mesopelagic species of acoustic surveys traditionally targeting epipelagic species has caused some surveys to increase their detection range. This has raised concern about the potential impact that the increase of ping rate, i.e., reduction of longitudinal resolution, might have on the acoustic estimates. The objective of this preliminary study is to test the effect of a successive ping rate reduction on the average of NASC values collected in real conditions, based on statistical means.

We chose three transects of the JUVENA 2010 survey targeting pure anchovy schools, belonging to the same homogeneous stratum and with a relatively high ping rate, ~0.3 s, close to the maximum one that can be achieved for a detection range of 200 m. The transect was echo-integrated by cells of 1 ping x 50 m, with a minimum threshold of -60 dB, covering the vertical distribution of anchovy in that stratum. To simulate the reduction of ping rate, we performed random resampling without replacement on the vector of NASC values (N = 108184), using a decreasing number of samples (N = 108000, 107000, …, 1000). The ping rates simulated ranged ~0.3 s to ~35 s. For each sampling resolution, we computed resampling 1000 times and computed the average of the NASC of the vector each time. Then we computed mean and median, as well as standard deviation and error of the mean of each resampled vector.

The results (Figure 1, Table 1) indicated a decrease in the descriptive random error (i. e., standard deviation) with the increasing ping rate, but an increase of the inferential random error (i.e., standard error), due to reduction of the sampling effort in the transect.

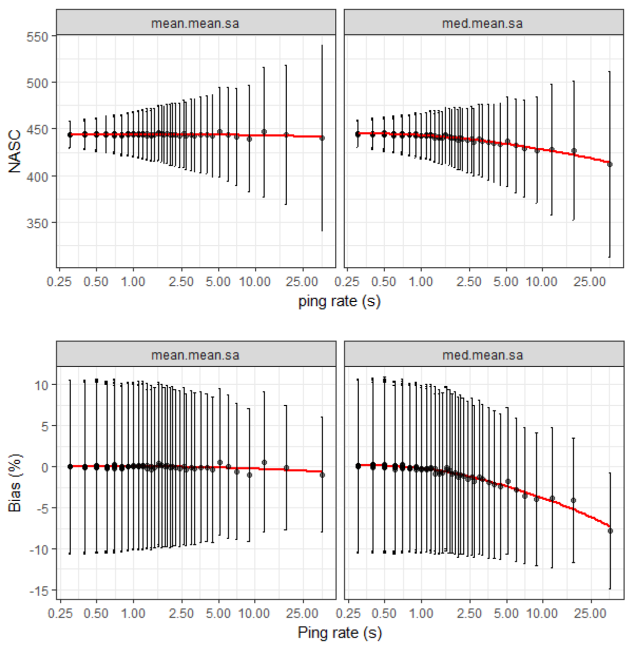



**Figure 1. Analysis of influence of ping rate on the average acoustic values distinguishing the two types of averaging, mean and med (for median), of the 1000 repetitions. Top: Evolution of the NASC values with the ping rate, the error bars representing standard error. Bottom: Evolution of the bias with the ping rate, the error bars representing standard deviation in CV. The range of typical ping rates used in the survey is 0.3-0.9 s.**

There is also a slight decrease of the averaged NASC values when the ping rate increases. This decrease is higher for the medians than for the means. When the highest values were removed (removing only 12 values from the more than 100.000 values, Figure 2) almost all the bias was removed (Figure 3), thus indicating that it was caused by the extremely skewed distribution of the NASC values. We conclude that the bias was caused by the higher probability of missing some of the few high values for lower longitudinal sampling resolution. We believe that this result is representative of fisheries acoustic data in general. Although, given that these high values were grouped in aggregations of pings of ~3 pings on average, using the pure random re-sampling protocol followed here, the bias obtained is likely to be overestimated in comparison with what it is expected with a more realistic sequential ping rate reduction. For the next WGACEGG meeting in 2019, this analysis will be updated with an improved resampling procedure.

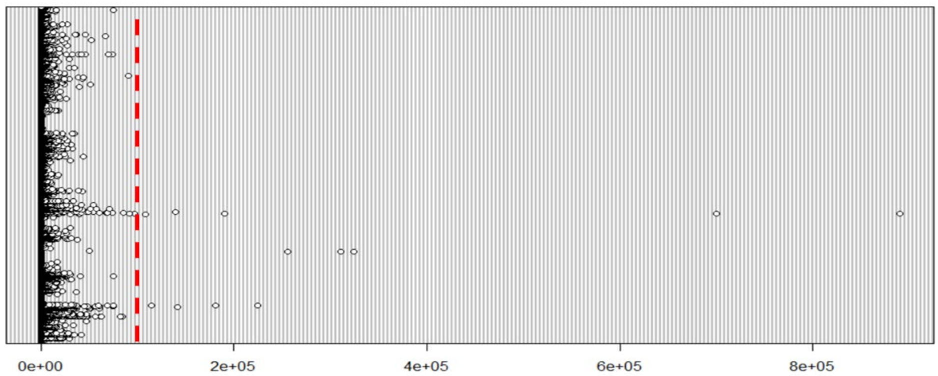



**Figure 2. Dotplot of the original (non-resampled) vector of acoustic values. The vertical dotted line indicates 100000 m²/nmi² and divides the 12 highest values from the rest of the set.**

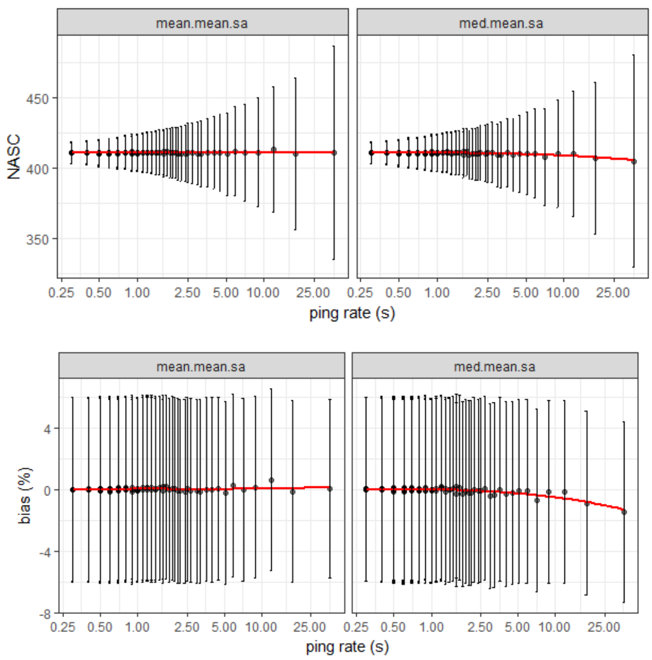



**Figure 3. Same analysis as in Figure 1 but after removing the 12 highest NASC values from the vector. Top: Evolution of the NASC values with the ping rate, the error bars representing standard error. Bottom: Evolution of the bias with the ping rate, the error bars representing standard deviation in CV.**

**Table 1: Summary of mean $s_A$ and errors derived from the resampling exercise simulating ping rate reduction for the two types of averaging used.**

| Av.type | ping.rate (s) | sa.mean ($m^2/nmi^2$) | Bias (%) | N | sa.sd ($m^2/nmi^2$) | cv.sd (%) | sa.se ($m^2/nmi^2$) | cv.se (%) |
|---|---|---|---|---|---|---|---|---|
| mean.mean.sa | 0.5 | 444 | 0 | 78000 | 4646 | 10.5 | 17 | 0.04 |
| mean.mean.sa | 1 | 444 | 0.02 | 38000 | 4515 | 10.2 | 23 | 0.05 |
| mean.mean.sa | 1.5 | 444 | 0.02 | 24500 | 4389 | 9.9 | 28 | 0.06 |
| mean.mean.sa | 2 | 444 | -0.02 | 18000 | 4310 | 9.7 | 32 | 0.07 |
| mean.mean.sa | 2.5 | 443 | -0.17 | 14000 | 4186 | 9.4 | 35 | 0.08 |
| mean.mean.sa | 3 | 443 | -0.16 | 11500 | 4127 | 9.3 | 39 | 0.09 |
| mean.mean.sa | 3.5 | 444 | -0.08 | 10000 | 4086 | 9.2 | 41 | 0.09 |
| mean.mean.sa | 4 | 444 | -0.1 | 9000 | 3998 | 9 | 42 | 0.09 |
| mean.mean.sa | 4.5 | 443 | -0.33 | 8000 | 3935 | 8.9 | 44 | 0.1 |
| mean.mean.sa | 5 | 447 | 0.58 | 7000 | 3984 | 9 | 48 | 0.11 |
| mean.mean.sa | 6 | 444 | -0.02 | 6000 | 3878 | 8.7 | 50 | 0.11 |
| mean.mean.sa | 7 | 442 | -0.58 | 5000 | 3690 | 8.3 | 52 | 0.12 |
| mean.mean.sa | 9 | 440 | -1.02 | 4000 | 3596 | 8.1 | 57 | 0.13 |
| mean.mean.sa | 12 | 447 | 0.56 | 3000 | 3801 | 8.6 | 69 | 0.16 |
| mean.mean.sa | 18 | 444 | -0.09 | 2000 | 3347 | 7.5 | 75 | 0.17 |
| mean.mean.sa | 35.5 | 440 | -0.95 | 1000 | 3133 | 7.1 | 99 | 0.23 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| med.mean.sa | 0.5 | 444 | 0.09 | 78000 | 4646 | 10.5 | 17 | 0.04 |
| med.mean.sa | 1 | 443 | -0.19 | 38000 | 4515 | 10.2 | 23 | 0.05 |
| med.mean.sa | 1.5 | 442 | -0.54 | 24500 | 4389 | 9.9 | 28 | 0.06 |
| med.mean.sa | 2 | 440 | -1 | 18000 | 4310 | 9.7 | 32 | 0.07 |
| med.mean.sa | 2.5 | 437 | -1.51 | 14000 | 4186 | 9.4 | 35 | 0.08 |
| med.mean.sa | 3 | 438 | -1.4 | 11500 | 4127 | 9.3 | 39 | 0.09 |
| med.mean.sa | 3.5 | 436 | -1.93 | 10000 | 4086 | 9.2 | 41 | 0.09 |
| med.mean.sa | 4 | 435 | -2.18 | 9000 | 3998 | 9 | 42 | 0.1 |
| med.mean.sa | 4.5 | 434 | -2.38 | 8000 | 3935 | 8.9 | 44 | 0.1 |
| med.mean.sa | 5 | 437 | -1.72 | 7000 | 3984 | 9 | 48 | 0.11 |
| med.mean.sa | 6 | 432 | -2.81 | 6000 | 3878 | 8.7 | 50 | 0.12 |
| med.mean.sa | 7 | 429 | -3.55 | 5000 | 3690 | 8.3 | 52 | 0.12 |
| med.mean.sa | 9 | 427 | -3.95 | 4000 | 3596 | 8.1 | 57 | 0.13 |
| med.mean.sa | 12 | 428 | -3.77 | 3000 | 3801 | 8.6 | 69 | 0.16 |
| med.mean.sa | 18 | 427 | -4.07 | 2000 | 3347 | 7.5 | 75 | 0.18 |
| med.mean.sa | 35.5 | 412 | -7.86 | 1000 | 3133 | 7.1 | 99 | 0.24 |

**FSP 2018-2019: Self sampling programme: Acoustic sprat survey in Lyme Bay.** Sílvia Rodríguez Climent

A Fisheries Science Partnership (FSP) survey was carried in parallel to the PELTIC18 survey to evaluate the sprat (*Sprattus sprattus*) population using fisheries acoustics and pelagic trawling in Lyme Bay (UK). Specific objectives were to identify the amount of sprat biomass that resides in the shallow inshore waters that could not be covered by the research vessel, the effect of patchiness on the detectability of sprat based on the existing and to compare the biomass estimated by the two surveys.

A portable Simrad EK60 echosounder (120 kHz) was side-mounted in the pelagic trawler *Mary Anne* and used to collect acoustic data along seven equidistant transects (5 nautical miles, nmi) perpendicular to the coast. The transects resembled the position of those conducted by the PELTIC survey although they were extended further inshore. The vessel speed during the acoustic transect was a constant 7 knots and ten opportunistic trawls were carried out to be able to identify the echo-traces.

At the time of writing the analysis was not completed but preliminary results suggested that despite two weeks of difference in the timing of the two surveys, the location of sprat was not significantly different within the bay: although sprat appeared widespread, the central and western transects contained the highest densities during both surveys. Other than quantifying sprat in the inshore areas, biomass calculated for Lyme Bay from PELTIC (at 38 and 120 kHz) will be compared with that recorded on the commercial sprat boat. The later will also be compared with two similar surveys conducted previously in the same area in 2011 and 2012. Finally, the effect of different transect resolution on biomass estimates will be conducted.

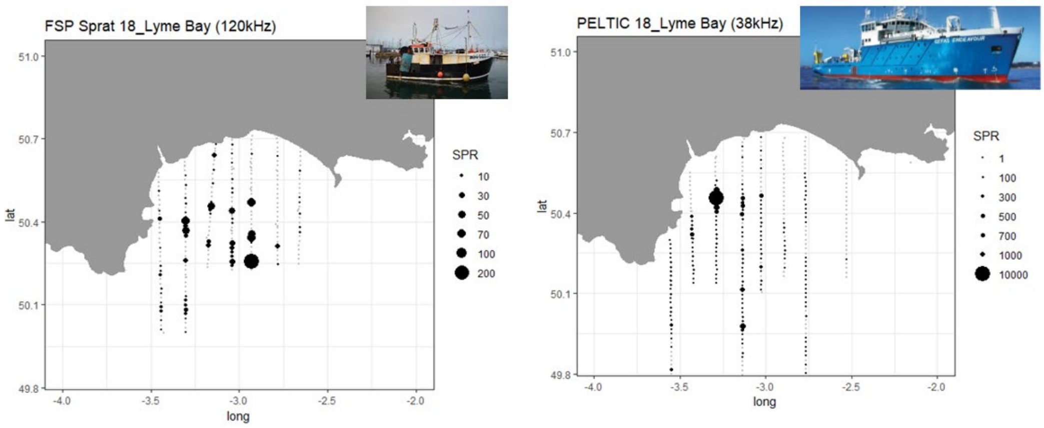



**Figure 1. Sprat NASC (m²/nmi²) values for the FSP survey (left) and PELTIC (right) carried out this fall 2018**

**Multibeam echosounder for fish school characterization.** N. Burgarella, L. Berger, M. Doray and P. Petitgas

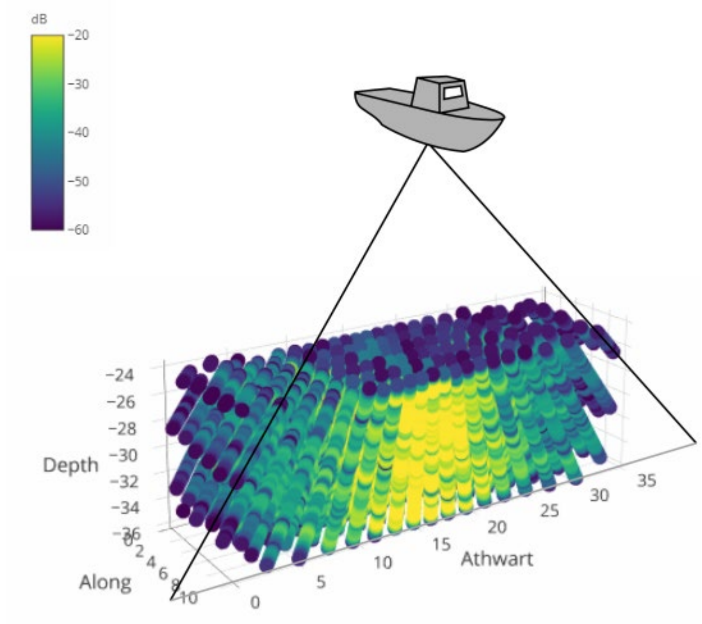
In stock evaluation and shoaling behavior study, multibeam echo-sounders can bring several benefits when compared to classical single beam echo-sounders. Access to three-dimensional data gives additional shape and structural information on shoals, therefore allowing for better identifications of the species forming the school. Additionally, multiple beams give access to a higher sampling volume.

There are, however, some drawbacks to the use of multibeam echo-sounders. Namely, a longer blind area near the transducer, and, with different beams having a different angle, the risk that fishes with a same orientation would be insonified with a different incidence angle depending on their position in the sounder fan.

Using a simulation approach, we search for areas of lower acoustic density on shoals created with a uniform density.

We find that, when individuals in a shoal are not aligned with the boat progression axis, differences in intensification angle can lead to the appearance, on the echogram, of areas appearing as having a lower density that do not correspond to actual changes in the density or orientation pattern of individuals in the shoal. This effect only appears on the axis athwart to the boat progression as it is the axis over which beam angle varies.

Multi-beam echosounders have many benefits compared to classical echo-sounders. Structural information acquired over the athwart axis should however be regarded critically while analyzing data from this type of sounder. In the situation of a stock evaluation conducted with a multi-beam echo-sounder, underestimation of densities on the external beams due to incidence angle variation could lead, over the course of a campaign, to an underestimation of stock size.




An example of a structure appearing on an echogram when the shoal density is uniform. 40 individuals/m$^3$, individuals yaw: 90° ± 5° from the boat progression.

**Characterization of Bay of Biscay sound scattering layers using broadband acoustics, nets and video.** Arthur Blanluet, Mathieu Doray, Laurent Berger, Jean-Baptiste Romagnan, Naig Le Bouffant, Sigrid Lehuta and Pierre Petitgas

Broadband acoustics were used to test the hypothesis on the gas bearing-based composition of the sound scattering layers observed during PELGAS spring survey. The forward approach was used to link the acoustic scattering to the biological sampling. This consisted on modelling the theoretical backscattering of the sampled organisms and compare it to the measured backscatter. Also, a clustering of the backscattering spectrum was performed to further investigate the composition and homogeneity at the different layers. Sampling was performed in two zones: the continental shelf and the slope, and three different layers were studied: daytime surface, daytime deep and night time surface layers.

Biological sampling was done by means of two nets: Multinet and MIK (Method Isaac Kid) and video recordings. The acoustic sampling was done with two EK60 narrow-band echosounders (18 and 38 kHz) and four EK80 broadband echosounders with maximum and minimum frequencies ranging from 47-420 kHz.

The reported results showed an important contrast in composition between the two zones: pteropods and big siphonophores dominating the continental shelf zone, while mesopelagic fish, copepods and euphasiids dominated the slope zone. A relevant mis-match between the modelled and measured Sv(f) was reported for the daytime layers (related to a low catchability of the organisms), but a good fit was observed in the night time layers (Fig. 1). The use of video cameras was recommended for sampling sy-phonophores. The results reported on the clustering analysis showed that the SSL presented generally more complex internal structure of spectra than the echogram´s visual homogeneity (Fig. 2).

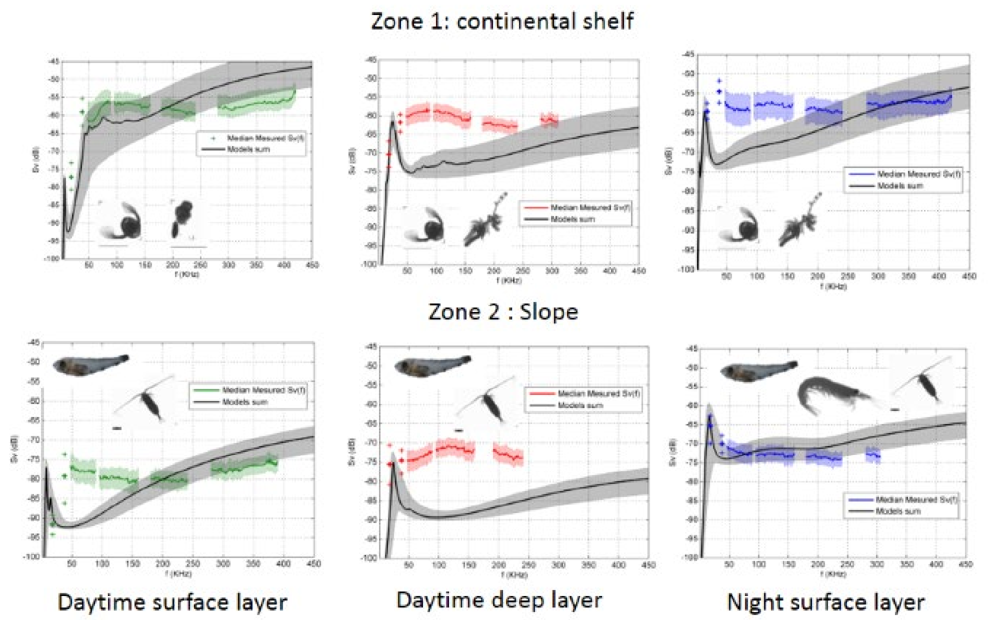



**Figure 1. Forward approach results at the two zones and three layers of study.**

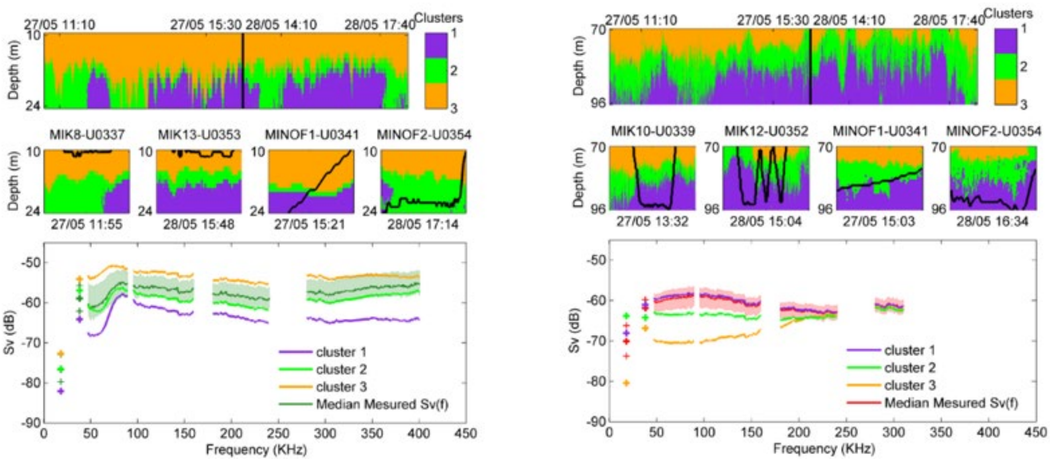



**Figure 2. Classification approach results for the 10-24 m layer (left) and the 70-96 m layer (right).**

**Echosonde project and Phoenix project (including update on EK80).** Mathieu Doray

Two large scale offshore windfarms are to be built near the French Pays de la Loire region coast. The impact of Marine Renewable Energy production units' impact on pelagic organisms is poorly known. Pelagic organisms are key ecosystem components, as they produce by photosynthesis and funnel the energy and biomass to upper trophic levels and other marine ecosystem components. The Ec(h)oSonde project aims at developing a prototype of integrated acoustic observatory to monitor the impact of renewable marine energy (RME) on coastal pelagic ecosystems. The Ec(h)oSonde demonstrator will be deployed in the SEM-REV sea testing site, next to the future Saint Nazaire's windmill field.

The Ec(h)oSonde project will lead to the development of an integrated acoustic observatory including an innovative broadband echosounder, Simrad EK80 operating in the 70, 120, 200 and 333kHz band. This will allow for a better characterization of pelagic targets based on acoustic data with the broadband technology compared to narrowband echosounders. The coastal pelagic ecosystem in the vicinity of the Ec(h)oSonde will be continuously sampled at high spatial resolution for the first time, providing new insights on the temporal dynamics of zooplankton and fish from diel to seasonal scales. The project will require the development of new data processing procedures to manage the big data flow from the observatory in near-real time.

The Ec(h)oSonde will be deployed in March-April 2019. Several sea surveys have been conducted in the Ec(h)oSonde area onboard small (20 m R/V Thalia) and large (70m R/V Thalassa, PHOENIX2018 survey) since June 2017. The objectives were to: i) test in-situ the Ec(h)oSonde echosounder, ii) collect biological data to groundtruth Ec(h)oSonde recordings and to characterise the local pelagic environment.

The Ec(h)oSonde echosounder allowed for the resolution and broadband acoustic characterization of individual, millimetric, mesozooplankton organisms up to 30 m away from the observatory. Thick Sound Scattering Layers (SSLs) made of zooplankton, small fish and jellyfish were consistently observed in the SEM-REV area in spring. SSLs were far less dense in autumn. Millimetric to centimetric jellyfish were the dominant organisms sampled in the SEM-REV area in spring. Extensive layers of dead plankton organisms were observed in spring 2018 during the PHOENIX2018 survey, following a strong microalgae bloom. Millimetric zooplankton crustaceans dominated the pelagic community in autumn.

Link to the EchoSonde project website: https://www.weamec.fr/en/blog/record_project/echosonde/

**Surface fish schools.** Mathieu Doray

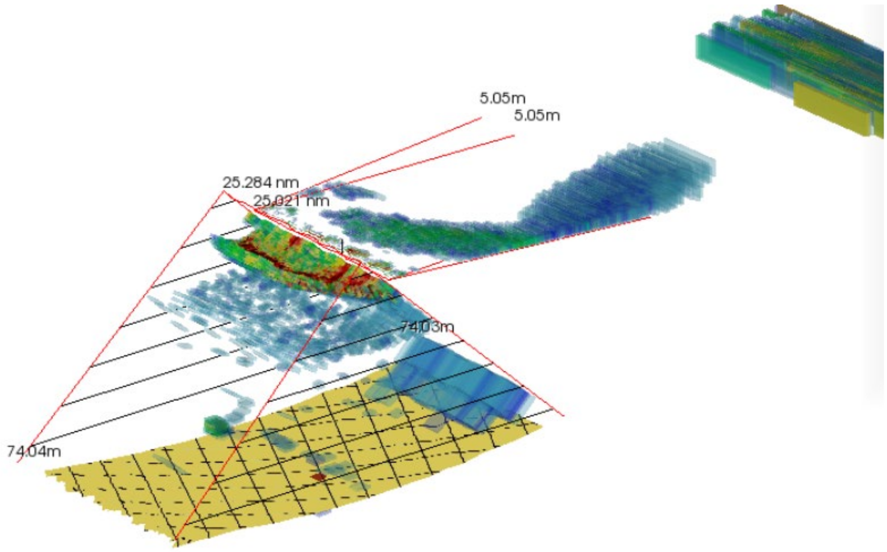



**Figure: acoustic sampling of surface school during the PELGAS2016 survey**

### Annex 5.3.2 Methodological developments for DEPM biomass assessment

**Imaging for the analysis of plankton: EcoTaxa.** Jean-Baptiste Romagnan

In the past 2 decades phytoplankton, zooplankton and ichthyoplankton (fish eggs) proved to be good indicators of long-term environmental changes, and important components in trophic and ecosystem studies in the context of fisheries science. This led to a renewed enthusiasm in re-analysing existing long-term plankton time series samples, and in developing high frequency, and high spatial coverage plankton and ichthyoplankton monitoring. As a consequence, the number of samples to analyse increased dramatically, and imaging instruments combined with semi-automated sample processing methods based on Machine Learning (ML) were developed as solution to optimize the time spent to assemble and elaborate this new data. However, an essential drawback remains: this data originating from imaging combined with ML must be scrutinized by humans' experts to be scientifically qualified. This step represents a major bottleneck in the analysis process, and several solutions can be envisioned: (i) improvement of automatic identification of imaged objects by the improvement of ML methods, (ii) better estimation and handling of the errors made by ML techniques, (iii) improvement of the ergonomy of the qualification process (made by experts).

EcoTaxa (Picheral et al., 2017) is a recently developed web-based application that bring solutions to points (i) and (iii) by proposing an interface dedicated to plankton imaging developed on the basis of experts' feedback, combined with up to date ML methods (Convolutional Neural Network, CNN), through an open platform that promote collaborative work, and hence the quality of data.

In this presentation I will:

(i) Briefly introduce how plankton and ichthyoplankton imaging can address modern marine science challenges

(ii) Present ecotaxa main features and functions

(iii) Show how and why EcoTaxa is an appropriate tool to address specific plankton and ichthyoplankton issues in the context of fisheries science through a practical example: the automatic sorting and staging of Anchovy and Sardine eggs ZooCAM images (Colas et al., 2018) originating from PELGAS 2017 exosystemic survey in the Bay of Biscay.

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Colas, F., Tardivel, M., Perchoc, J., Lunven, M., Forest, B., Guyader, G., et al. (2018). The zoocam, a new in-flow imaging system for fast onboard counting, sizing and classification of fish eggs and metazooplankton. Progress in Oceanography 166, 54–65

**The use of the CUFES in acoustic surveys to estimate the egg abundance of mackerel (*Scomber scombrus*) and horse mackerel (*Trachurus trachurus*).** Díaz Paz, I. González and P. Carrera

For the first time in the Spanish acoustic-trawl survey series (PELACUS) and in the International Blue Whiting Spawning Survey (IBWSS) the Continuous Underway Fish Egg Sampler (CUFES, Checkley *et al*., 1997) was used to estimate the quantitative egg abundance of mackerel and horse mackerel. Two areas with a different sampling grid were prospected, the Porcupine Seabight (IBWSS) and the Northern Spanish waters. In Porcupine Seabight the sampled was performed during day and nighttime and few eggs of mackerel and horse mackerel were found. On the North Spanish waters, sampled was carried out during daytime with a total of 94315 mackerel eggs counted. Mackerel eggs without embryo (stages 1a and 1b) were sorted and counted from those with embryo in different stages of development. Around 27 % of eggs sampled had not embryo and 73 % had embryo. This working document provides a summary of the abundance and distribution of mackerel and horse mackerel. In addition, the document discusses the advantages of the use of CUFES as a complement to the information obtained in the triennial mackerel and horse mackerel egg survey, an ICES-coordinated international survey in the north east Atlantic.

**Introduction**

The Spanish spring acoustic-trawl time series PELACUS started in 1991, covering the northern waters of the Iberian Peninsula (ICES sub-Divisions 8c and 9a-North), between the Spanish-Portuguese border and the Spanish-French one. Since 2013, when R/V Thalassa was substituted by the Spanish one Miguel Oliver (MO), the surveyed area, which until 2012 only covered from shoreline (e.g.30 m depth to the 200m isobath, was also extended up to the 1000 m one in order to make available the bulk of the blue whiting distribution.

On the other hand, in 2000, under the frame of the DG FISH project "PELASSES", PELACUS, as the Portuguese PELAGO and French PELGAS time series, incorporated the Continuous Underwater Fish Egg Sampler (CUFES) together with the routinely collection of other systematic measurements (SSS, SST, Flourometry, CTD+rossete casts, plankton hauls to determine primary production or dry weight at different sizes among other biological descriptors of the water column, etc.). In addition, the 120 kHz frequency started to be used to help discriminate between different fish species. During this period, acoustic estimates were also provided for non commercial species such as bogue or boar fish. In 2007, new frequencies (18, 70 and 200 kHz) were incorporated and a new team used the survey as a platform to obtain data on presence, abundance and behavior of top predators (marine mammals and seabirds). Together with these data, information on floating litter (type, number and position) and on other human pressures such as fishing (number of boats, type, activity, etc.) started to be routinely collected. Since 2014 the pelagic ecosystem characterization was complemented with records on subsurface microplastics obtained from opportunistic manta trawl hauls. In 2018 the IEO, on account the agreements on the Data Collection Framework (DCF-Common Fisheries Policy) that established Spain should provide fishery-independent biological information on blue whiting, has for the first time participated in the International Blue Whiting Spring Survey (IBWSS). Currently this survey is carried out by research vessels from Ireland, Norway, Faroës and The Netherlands, covering the core area of the blue whiting distribution on its main spawning ground. This is located around Porcupine, Rockall, Hatton, George Bligh, Bill Baileys, Rosemary and Faeroe banks. The coverage should be as much synoptic as possible, which requires a fine coordination among all vessels to ensure the area is surveyed in less than 21 days at the beginning of the spring (i.e. from March 21st to April 13th). Survey methods and strategies are described in the Manual for International Pelagic Surveys (ICES 2015). This year IEO should cover the outer part of the core area, round Porcupine Seabight, in order to analyze whether this would also be a spawning area. This survey has been done before the PELACUS one, which, in order to optimize vessel time, has started at the inner part of the Bay of Biscay instead of the normal start around the Spanish Portuguese border.

To survey Porcupine Seabight IEO has adapted the PELACUS methodology to the specific requirements of the IBWSS survey. Namely, instead of a grid with random start with transects 8 nmi apart and equally spaced, a grid with distance of 30 nmi among transects in the southern part and 20 nmi in the northern part was used. In the same way, acoustic was recorded 24 hours instead only day time hours. The rest of the sampling program to characterize the pelagic ecosystem remained invariable. This means that for the first time CUFES samples has been taken in Porcupine Seabight during an acoustic survey targeted on blue whiting. Besides, for the first time, mackerel eggs were sorted out, split into two categories (non embryo and with embryo) and counted.

This WD analyses the results obtained on mackerel and horse mackerel egg distribution and abundance obtained during the combined IBWSS-PELACUS survey carried out on board R/V Miguel Oliver by IEO. The implication of these findings on the next mackerel and horse mackerel egg surveys is also discussed. Finally, some recommendations for further studies aimed at to improve the knowledge on the first life stages of these species and provide a useful insight to the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS) are also pointed out.

### Material and methods

As explained before, coverage in Porcupine Seabight (IBWSS) followed the recommendations of the IPS. The area was prospected with a a systematic grid with random start, tracks 30 nmi apart in the southern part, 20nmi in the northern part, from self-break in the eastern limit to 13°W in the western limit (Figure 1). PELACUS survey design (ICES, 2018) consisted in a grid with systematic parallel transects with random start, separated by 8 nm, perpendicular to the coastline, covering the continental shelf from 40 to 1000 m depth and from Portuguese-Spanish border to the Spanish -French one (Figure 1). The starting point of each transect is located close to the coast (1-1.5 nm away from the shoreline). The end point of each transect can be also extended if shoals are detected in deeper waters. Contrary to previous years, the starting point of the survey was located at the inner part of the Bay of Biscay (i.e. Spanish-French border) instead the southern point at the Spanish Portuguese border.

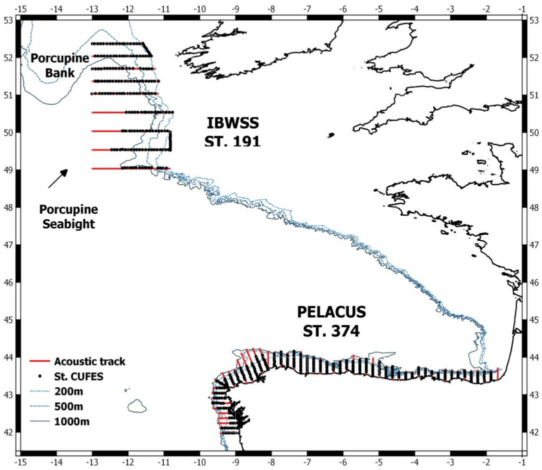


**Figure 1. Survey track (red) and CUFES stations (black) in IBWSS and PELACUS. Note southern tracks only steamed up to the westernmost station in IBWSS survey.**

The Continuous Underway Fish Egg Sampler (CUFES) was used to record the eggs found at 5m depth with a net mesh size of 335µm (Table 1). CUFES system uses an internal pumping system with the intake located at 5 m depth. The sea water goes first to a tank of about 1m3 before to be pumped towards the concentrator. The CUFES system had a flowmeter to measure the volume of the filtered water (600 l $min^{-1}$.) and a GPS (Geographical Position System) to provide sampling position and time. All these data were registered at real time using the integrated EDAS (Environmental Data Acquisition System) with custom software.

CUFES samples were taken every 3 nm while acoustic prospection of the transects. Once the sample is taken it is fixed in a buffered 4% formaldehyde solution. Anchovy, sardine egg, blue whiting, mackerel and horse mackerel egg, were sorted out and counted onboard under the microscope in order to obtain a preliminary data of abundance and distribution. Eggs being also preserved in the same solution.

In addition, this year mackerel eggs from CUFES samples were staged according to two stages of development classification; “no embryo” and “embryo”. Within WGMEGS the eggs of mackerel are classified into one of six morphological stages (Ia, Ib, II, III, IV and V; Lockwood et al., 1981). In this study “no embryo” stage corresponds to 1a and 1b and the “embryo” categorization is formed by grouping stages II, III, IV and V.

Simultaneously, continuous records of salinity, temperature and flurometry are taken using a SeaBird Thermosalinograph (TSG) coupled with a Turner A10 Flurometer.

**Table 1. General sampling in Porcupine Seabight (IBWSS) and Spanish Cantabrian waters (PELACUS).**

| | IBWSS 0318 | PELACUS 0318 |
|---|---|---|
| **Area** | 7j-k, between 49°N-52°30’N and 13°W -11°45’W | 8c + 9a North ICES |
| **Date** | 14-20/03/18 | 24/03/18-18/04/18 |
| **Tracks** | 9 plus 2 inter-transect | 32 |

| | |
|---|---|
| **Water intake** | 5 m depth |
| **Filtered water** | 600 l min$^{-1}$ |
| **Frecuency** | 3 nmi/sample |
| **Mesh size** | 335µm |
| **TSG** | SST, SSS and fluorometry |

**Results**

International Blue Whiting Spawning Survey

The IBWSS survey was performed onboard R/V Miguel Oliver from 11th to 23th March, with a total of 7 days at survey area (from 14th to 21st). Due to operational reasons, the southern planned transects could not be performed on the whole.

Weather conditions were rather bad, with wind strength reaching force 8 during most of the working days and mainly blowing from south, west, northwest and east; swell height has reached up to 4 m. Surface temperature and salinity ranged between 10.3-12.5 ºC and 35.5-35.8 ‰ respectively. CTD casts performed in this area showed a typical winter conditions without water stratification within the first 300 m of the water column.

A total of 191 CUFES (Figure 2 and Table 2) station were performed over 560 nautical miles prospected by acoustic track, with a 17.3 % of positive stations. Mackerel eggs were scarce and showed a distribution between 100 and 200 m depth isobaths. A total of 140 mackerel eggs were collected and the highest density by station was 2.33 eggs/m$^3$.

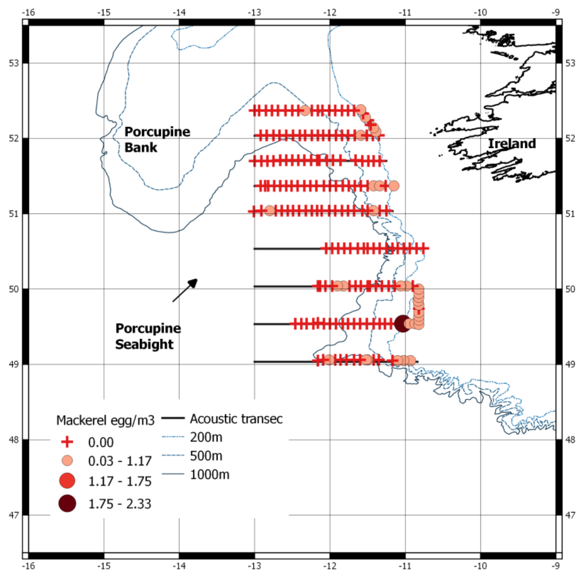


**Figure 2. Survey track, CUFES stations and mackerel egg abundance (egg/m$^3$). Station with no eggs (+, red). Note southern tracks only steamed up to the westernmost station.**

**Table 2. Summary of the sample in Porcupine Seabight (IBWSS) and Spanish Cantabrian waters (PELACUS). Nautical miles sampled (nm), number of stations, positive stations (stations with eggs, + stations), total eggs counted, maximum eggs by station and maximum egg density (eggs/m3) for mackerel.**

| *S. scombrus* | **IBWSS 0318** | **PELACUS 0318** |
|---|---|---|
| **Tracks** | 9 + 2 inter-transect | 32 |
| **nm sampled** | 560 | 1054 |
| **Nb. station** | 191 | 374 |
| **+ station** | 33 | 184 |
| **Total eggs** | 140 | 94315 |
| **Max. eggs /st.** | 26 | 2616 |
| **Máx. eggs/m³** | 2.3 | 234 |
| **SST ºC(min/mean/max)** | 10.3/11.8/12.7 | 12.7/13.2/14.6 |
| **SSS ‰ (min/men/max)** | 35.5/35.7/35.8 | 27.5/35.5/36 |

PELACUS survey

The first part of PELACUS 0318 survey was performed onboard R/V Miguel Oliver from 24th March to 18th April, with a total of 25 operative days of work (Table 1).

As happened in Porcupine Seabight, weather conditions were those of the winter time, with several storms throwing during the survey period. As a consequence, no stratification in the water column was observed nor, a maximum of chlorophyll. Temperature and salinity ranged between 12.7-14.6 ºC and 27.5-36 ‰ respectively.

In the ICES 8c and 9a North divisions a total of 374 CUFES samples were obtained over the 1054 nm prospected within the acoustic transect. From those samples, 364 were positive for mackerel eggs (Table 2 and Figure 3). A total of 94315 eggs were counted and the maximum number of mackerel eggs registered in a station was 2616. The maximum mackerel density recorded was 234 eggs/m³.

The mackerel eggs from CUFES were widespread distributed reaching the 1000 m depth isoline. The greatest densities were found near the Peña Cape (Asturias) within the platform and over the 1000 m depth isoline (Figure 3).

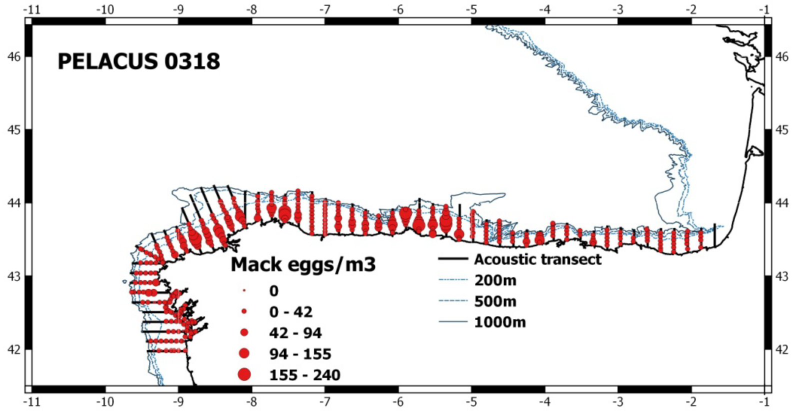


**Figure 3. Mackerel egg distribution and abundance (egg/m$^3$) from CUFES sampling.**

Eggs classified "No embryo" represented the 27 % (Ia and Ib stages) of the total mackerel eggs counted and staged. Eggs with "Embryo" corresponded to a 73 % (II, III, IV and V stages) of the whole sample (Figure 4). No differences were found between abundances by stage and daytime sampled.

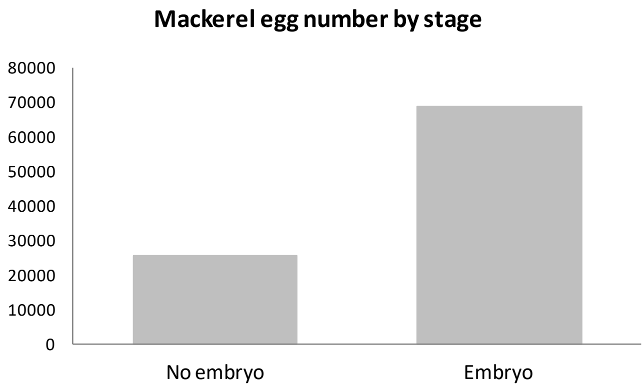


**Figure 4. Number of mackerel eggs counted by development stages. "No embryo" equal to 1a and 1b (Lockwood et al., 1981) and "Embryo" equivalent to stages II, III, IV and V.**

For horse mackerel, 271 of the 374 stations performed were positive, representing the 72.5 %. The total number of eggs was 4293, with a maximum density of 25 eggs/m$^3$ (Figure 5). Horse mackerel eggs were found widespread distributed, with a low density and very coastal area distributed. In the western part, the distribution expanded more off-shore than in the Cantabrian Sea.

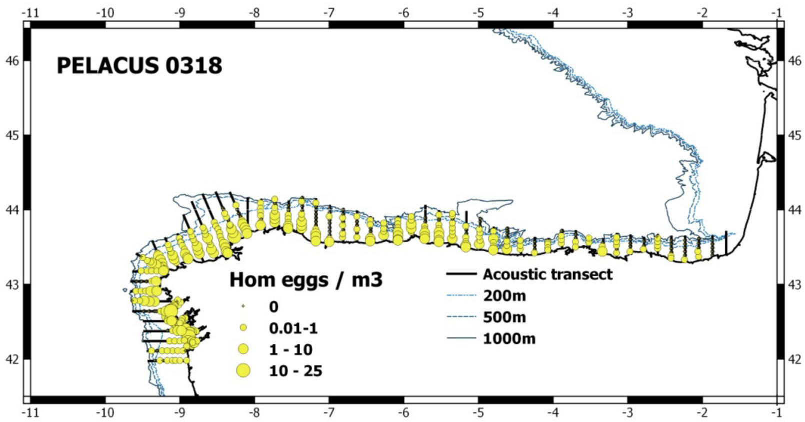


**Figure 5. Horse mackerel egg distribution and abundance (egg/m$^3$) from CUFES sampling.**

### Discussion

For first time, CUFES was used to estimate the egg mackerel abundance by stage category (without embryo and with embryo). This estimate, together with that obtained for horse mackerel could be use as proxy of the egg abundance while could be also used at the WGMEGS to know the evolution of the spawning peak of both species in years between the triennial mackerel and horse mackerel egg survey.

Mackerel egg spatial distribution matched with that estimated for adults from the acoustic records, with the bulk of the distribution being located close Cape Peñas and also Ribadeo area (westernmost part). However, adults showed a more coastal distribution, with the bulk of population located between 20 to 120 m depth, being negligible at deeper waters. Further studies focusing on the spring eddies and other mesoscale processes in this part of the Bay of Biscay should be needed in order to explain the greater extension of the egg distribution.

The great difference found in egg abundance between Porcupine Seabight and Cantabrian Sea would be related with the scarce number of adult fishes in the surveyed area. Effectively, few mackerel were recorded at 120 and 200 kHz echograms. However, it could be also an indication of the lack of mackerel spawning in the surrounding area; the lack of mackerel eggs even in the CUFES samples obtained close to the self-break when steaming the intertransect could support it.

CUFES is a valuable tool to estimate the spawning area and also to identify the hot spots of the adult concentrations. It can be used to make and adaptive sampling strategy, by increasing the sampling intensity on those area with higher variability (hot spots).

For the time being its use is only qualitative as no model has been developed to estimate the egg abundance along the water column at the different scenarios of water column density along the surveyed area. The amount of egg collected in PELACUS is a promising result, but the relation between the egg abundance at 5 m depth and the whole water column and between pumping performance of the vessel collecting egg at 5 m depth and the true egg abundance at this depth should be studied. During PELACUS, several oblique multinet tows have been done. Although the results will be analyzed after the survey, more multinet tows would be needed in order to characterize the water column mackerel egg distribution in coastal waters, subjected mainly to a tidal and river flow processes among other, continental self, self-break and open ocean waters. Besides, incidental information from the manta trawl tows done during this survey is showing a great amount of mackerel egg at surface and subsurface layers.

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